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OCONEE RIVER WATER QUALITY AND SEDIMENT ANALYSIS,(U)

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OCONEE RIVER

WATER QUALITY AND SEDIMENT ANALYSIS

NOVEMBER 1977

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER 6	2. GOVT ACCESSION NO. AD-A101 984	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) OCONEE RIVER WATER QUALITY AND SEDIMENT ANALYSIS		5. TYPE OF REPORT & PERIOD COVERED
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) R. G. Willey, Jess Abbott and Michael Gee		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army Corps of Engineers The Hydrologic Engineering Center 609 Second Street, Davis, CA 95616		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS 11		12. REPORT DATE November 1977
		13. NUMBER OF PAGES 123
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Distribution of this publications is unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Water Quality, River, Computer Application, Land Use, Impact Analysis.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Stream water quality modeling is applied to a practical case showing impact analysis regarding future alternative land use.

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

OCONEE RIVER
WATER QUALITY AND SEDIMENT ANALYSIS

FINAL REPORT TO THE SAVANNAH DISTRICT

BY

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November 1977

OCONEE RIVER

WATER QUALITY AND SEDIMENT ANALYSIS

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I INTRODUCTION

BACKGROUND

This study of the water quality of the Oconee River Basin was conducted as part of the expanded scope Flood Plain Information (XFPI) study done by the Savannah District Army Corps of Engineers. The Savannah District undertook this first pilot XFPI study in which geographic data banks were used as the basis for simulating watershed hydrology, and the computation of expected annual flood damages. Environmental considerations were also included in the original pilot study objectives but mainly for appraisal of wildlife habitat and tradeoffs between the desirability of certain land uses. The primary intent of the XFPI analysis was to analyze the effects of alternative futures of the Oconee River Basin development in a systematic manner such that realistic comparisons of flood hazards, flood damages, and environmental quality could be made between existing and alternative future watershed development patterns.

After the viability of the XFPI geographic data bank methodology had been successfully demonstrated for flood hazard and damage computations, the Savannah District requested the HEC to perform an Oconee River Basin water quality study consistent with the XFPI objectives and methodology. Thus, the existing and alternative future water quality of the Oconee River, within the study area, would be simulated using the geographic data bank as the basis for land use inputs to existing HEC water quality simulation models. The Storage, Treatment, Overflow, Runoff Model (STORM) [1] would be used for determining the quantity and quality of land surface runoff and dry weather flow and the Water Quality for River/Reservoir Systems Model (WQRRS) [2] would be used to simulate water quality in the river network. That is, the land surface runoff from STORM would be input to WQRRS which would combine all inflows to the Oconee River and simulate the resultant river water quality.

Some historical data about the water quality of the Oconee River Basin were said to be available but the extent and appropriateness of those data for these modeling purposes were not known. The HEC undertook the water quality studies expecting that the historical data would be satisfactory for model calibration for existing conditions. If some aspects of these data were not sufficient, then general experience from other water quality studies would be used to ascertain acceptable performance of the simulation models.

The Savannah District also requested the HEC to study the land surface erosion simulation possibilities using the geographic data bank. In particular, it was desirable to erode and transport sediment on a grid cell basis as defined by the topography stored in the geographic data bank. A new computer program would be developed to implement this proposed methodology.

SCOPE AND OBJECTIVES

The objective of the HEC study was to investigate the applicability of the HEC water quality simulation models, STORM and WQRRS, for usage in XFPI studies. This was to be accomplished through an evaluation of the water quality impacts of existing and alternative future land use development patterns in the Oconee River Basin. The new HEC grid cell sediment transport model would be evaluated in a similar manner. The methodologies for analysis of water quality and sediment transport were to be consistent with the philosophy (i.e., use of geographic data banks) of the ongoing XFPI pilot study.

The land use data required by the STORM model were to be obtained from the geographic data bank through the Hydrologic Parameters (HYDPAR) utility program. STORM would also access the land use data for computation of sanitary sewage flows. Certain changes were required in STORM to utilize the grid cell data bank. The HEC would calibrate the models on existing data and use the calibrated models to simulate alternative future watershed developments.

STUDY TEAM

This study was to be carried out entirely by the HEC with minimal direct involvement of Savannah District personnel. The district was to provide general guidance about the XFPI study, the objectives of this study, and supply existing water quality and sediment data to the HEC. Because this study was a special investigation of the applicability of new techniques in support of the XFPI study, the district did not feel it was necessary to have this water quality modeling expertise developed within their staff. The district staff could be trained in the use of this methodology at a later date if warranted by their needs and the results of this study.

The HEC conducted the study as a team effort with Mr. Jess Abbott being responsible for the application of the STORM model, Dr. Michael Gee being responsible for the grid cell sediment transport investigations, and Mr. R. G. Willey being responsible for the application of the WORRS model. Messrs. Darryl Davis and Pat Webb provided guidance on the XFPI methodology and the utilization of the geographic data bank. Mrs. Marilyn Hurst and Mr. Paul Ely performed most of the detailed tasks involved to complete the project. The drafting was done by Mr. Roger Nutter.

II SUMMARY AND CONCLUSIONS

SUMMARY

The study objectives were carried out as proposed. The development, modification, and implementation of the mathematical models provided the means to simulate existing and assess the future water quality and sediment transport characteristics of the Oconee River Basin study area. The STORM and WQRRS water quality modeling methodology was successfully implemented; however, the lack of adequate data to calibrate these models made their application difficult and the results unsubstantiated except for general comparisons with experience from similar studies.

The grid cell land surface erosion and sediment transport methodology was not entirely successful because of problems in using the topography file of the geographic data bank. The erosion/sediment transport methodology was based on continuously downhill sloping grid cells to the stream collection network. Upon application of the method using the Oconee topography file, it was learned that the grid cells did not slope continuously downhill to the collection channels. A concentrated effort was made to incorporate the required slope continuity into the geographic data bank. This problem could not be resolved within the scope of this investigational effort. If further development of this methodology is desired, the erosion/sediment transport methodology must be modified to accept the existing data bank topography or the topographic data must be edited to conform to the slope-continuity assumptions made in the mathematical model.

The STORM and WQRRS interfaces with the data bank were developed simultaneously with assembly of historical data required to operate and calibrate the models. It soon became evident that very few historical water quality measurements had been made in the Oconee River and its tributaries. Thus, the calibration of the models would have to be based on theory and experience. Some water quality measurements had been made and these data were used as much as possible. No data were available for the important storm runoff periods during which land surface pollutant washoff occurs. Concentrations of pesticides, heavy metals and other parameters were not specifically mentioned and not evaluated in this study. Such parameters cannot be simulated presently by STORM and WQRRS.

The decision was made to continue with the STORM-WQRRS modeling effort without adequate data. This was done mainly so that the general methodology could be developed. Had it not been for the desire to develop and demonstrate the STORM-WQRRS methodology for XFPI studies, a more simple water quality study would have been recommended for the Oconee study. The recommended water quality study methodology would have been commensurate with the detail of existing data and the degree of detail warranted by the study objectives.

Assumptions were made about the basic water quality inputs from the Upper Oconee River (outside the study area) and about the land surface runoff within the study area. Because there were no data on the river water quality during storm events, the calibration of reasonable values of land surface runoff and incoming river water quality required much more time than anticipated. The land surface runoff simulation was reviewed in some detail for Reaches 1 and 2, Figure III-3. Upon achieving reasonable results for these reaches, it was assumed that subsequent reaches simulated in a similar manner would also have reasonable results. Thus, the other basins were simulated and it was not until all of the basins were aggregated in the WQRRS receiving water model that it was apparent some basin results were unreasonable. The complexity of the WQRRS model did not facilitate the timely appraisal of these potential problems. At that late date in the study, some of the basin land surface runoff simulations had to be rerun and the river system was simulated again. The new results were acceptable. The land surface runoff from the basins should have been reviewed more thoroughly during the initial simulations; however, such review was not emphasized because of the data limitations.

The existing land use condition was simulated using non-point source land surface runoff, point sources within the tributary subbasins, and point source inputs from the two main sewage treatment plants in the study area. The treatment plant loads appear to cause the most significant impact on the North Oconee River for existing conditions. The pollutant loadings from the sewage treatment plants on the North Oconee contribute approximately 80-93% (depending on the parameter) of the total loads (point and non-point sources). Therefore further reduction in the loads from sewage effluent would appear to have the greatest effect in upgrading the water quality for existing conditions. There does not appear to be a significant water quality problem under existing conditions because, with the possible exception of coliforms, established water quality standards are not exceeded.

The basins having the most significant impact are 1A, 2, and 3 on the North Oconee and 6A, 6B, and 16 on the Middle Oconee, Figures III-1 and III-2.

The sewage treatment plant effluents on the Middle Oconee contribute 48-80% of the total loads reaching the Middle Oconee above the confluence. The concentrations do not exceed established water quality standards under the existing development with the exception of coliforms. The most immediate improvements could be made by reducing the loads from treatment plants.

The North Oconee River watershed contributes a significantly larger pollutant load to the Main Oconee River than does the Middle Oconee River. The North Oconee watershed has significantly larger loadings from the sewage treatment plants. Specifically the North Oconee plant contributes about 70% of the total load (point and non-point sources) to the Main Oconee River. In addition, effects of the loadings from the treatment plants are much more pronounced in the North Oconee than the Middle because the natural flows from the upstream watershed on the North Oconee provide much less dilution.

The future water quality for the Oconee River study area was simulated for the Alternative C, Table III-1, land use development plan. In general, the sources of water degradation are the same as those defined for existing conditions. On the North Oconee the contributions due to treatment plant loadings ranged from 81-88% of the total loadings and on the Middle Oconee the plant loadings contribute 48-88% of the totals.

While the percentage contribution from sewage treatment loads appears to remain constant, the total loads have increased somewhat from existing to the alternative future C. The increases are not major due to the relatively small percentage change in land use change in the total study area. The major impacts were shown to be in subbasins 1A, 2, and 3 on the North Oconee and 6A, 6B, and 16 on the Middle Oconee because these subbasins experienced the greatest degree of urbanization. These subbasins and the loadings from the 2 main treatment plants tend to create "shock loadings" in the reaches immediately downstream of the effluent outfalls or tributary inflows.

CONCLUSIONS

Conclusions with respect to both the technical feasibility and the suitability of the methodology for water quality and land surface erosion/ sediment transport studies in support of the XFPI program will be made in this section. The impact of the future land use plans on Oconee River water quality were discussed in the preceding Summary Section. The study objectives, budget, and availability of data to support the proposed study methodology are important factors in determining the most appropriate technology for a project. The STORM and WQRRS water quality simulation models have been shown to be technically feasible for water quality studies. The appropriateness of their use for XFPI studies is a much more important question which can only be determined by the water quality objectives of each study application. The STORM and WQRRS computer programs and attendant study methodology are quite appropriate for detailed water quality studies. That is, these models provide a good simulation of the physical water quality system, both for land surface runoff and receiving waters. The STORM model provides a relatively simple simulation of land surface runoff. The WQRRS model performs a rather complex simulation of receiving water quality and requires much more comprehensive input data than does STORM.

The general objective of XFPI studies is the analysis of the hydrologic, economic, and environmental impact of future land use development patterns. To accomplish this, the existing system must be represented satisfactorily in simulation models. There must also be a consistent, logical means to generate and compare alternative futures. Because there are so many unknowns with respect to specific location and type of future land use patterns, river regulation, and waste water management facilities, the analysis of futures can be less detailed than known conditions. Methods should capture the essence of the future conditions without being overly complex about the specific types and locations of the development.

In accordance with the above objectives, the STORM model provides both the type of information and the level of technical detail which are appropriate for XFPI studies. The basic land use parameters of the STORM model are readily derived from the geographic data bank. Other input to the STORM model can be easily obtained or estimated from previous experience.

For application of the STORM model, continuous rainfall and runoff data are recommended for a period of several years to calibrate the hydrologic parameters of the model. Pollutant loadings at the subbasin outlets should be measured throughout several major storm events during the multiyear hydrologic calibration period. If these data are not available, the STORM model should not be used unless acceptable results can be obtained from use of coefficients derived from similar studies. The availability of data should be determined early in the study so that data collection efforts cannobe arranged as necessary.

The water quality simulation capability of the WQRRS model seems to be more comprehensive than required for the general XFPI study. The many data requirements limit the utility of this model. The WQRRS model would be required if a more comprehensive understanding of the water quality condition is desired. This might be the case for reservoir regulation studies or major river/reservoir studies with specific water quality objectives. For the XFPI level of complexity, a more simple receiving water analysis seems appropriate. An analysis commensurate with the complexity of the STORM model is desirable. The HEC is presently developing that type of simplified receiving water model.

If a detailed water quality study had been required for the Oconee XFPI study, then data collection efforts should have been started as soon as it was determined that the historical data were inadequate. The collection and analysis of field data would have required a considerably larger study budget, on the order of 8 to 10 times the initial water quality study budget of $20,000.

For application of the WQRRS model, climatic, pollutant point-source loading data, and/or results from STORM must be known for the entire calibration period. Most importantly, in-stream water quality measurements must be available for several major parameters both during storm runoff periods (preferably the same periods as used for STORM) and low flow or other critical water quality periods. These data should be available for at least one location in the river system depending upon how much variation there is in the land use and stream regimes in the river network. If only one location were available, it should be at the downstream boundary of the river network so that the integrated effects of the land surface runoff and in-stream quality changes are measured.

III OCONEE RIVER SYSTEM DATA AVAILABILITY

GENERAL

The Oconee River begins in the Georgia counties of Barrow and Jackson north of Athens and flows south through the middle of Georgia. After it joins the Ocmulgee River near Hazlehurst, it becomes the Altamaha River which flows southeast to the Atlantic Ocean. A location map is shown in Figure III-1.

The study boundaries for this project include the Oconee River drainage between the Currey Creek dam site on the North Oconee and the State Highway Bridge 33 on the Middle Oconee down to a location 8 miles below Barnett Shoals Dam on the Main Oconee (i.e., inflow to Wallace Reservoir). The Oconee River study area is shown in Figure III-2 and schematics of the study area are shown in Figures III-3 and III-4. The schematics include the location of all major tributaries, sewage treatment plant effluents, and the Athens water supply intake.

The historical period to be used for analysis was selected using the following criteria:

(1) A low flow period.

(2) A period with several significant rain events.

(3) A relatively recent period (i.e., existing conditions).

(4) A short duration (i.e., one month).

Water quality sampling points were located on the Middle Oconee River in 1970 and on the North Oconee in 1974. During 1970-1975, the dryest one month period having 3 to 4 significant rain events was October 1970. This period has as much available water quality data as any period in 1970 to 1975 and was therefore selected for analysis.

The various aspects of specific data availability will be discussed in the remainder of this chapter.

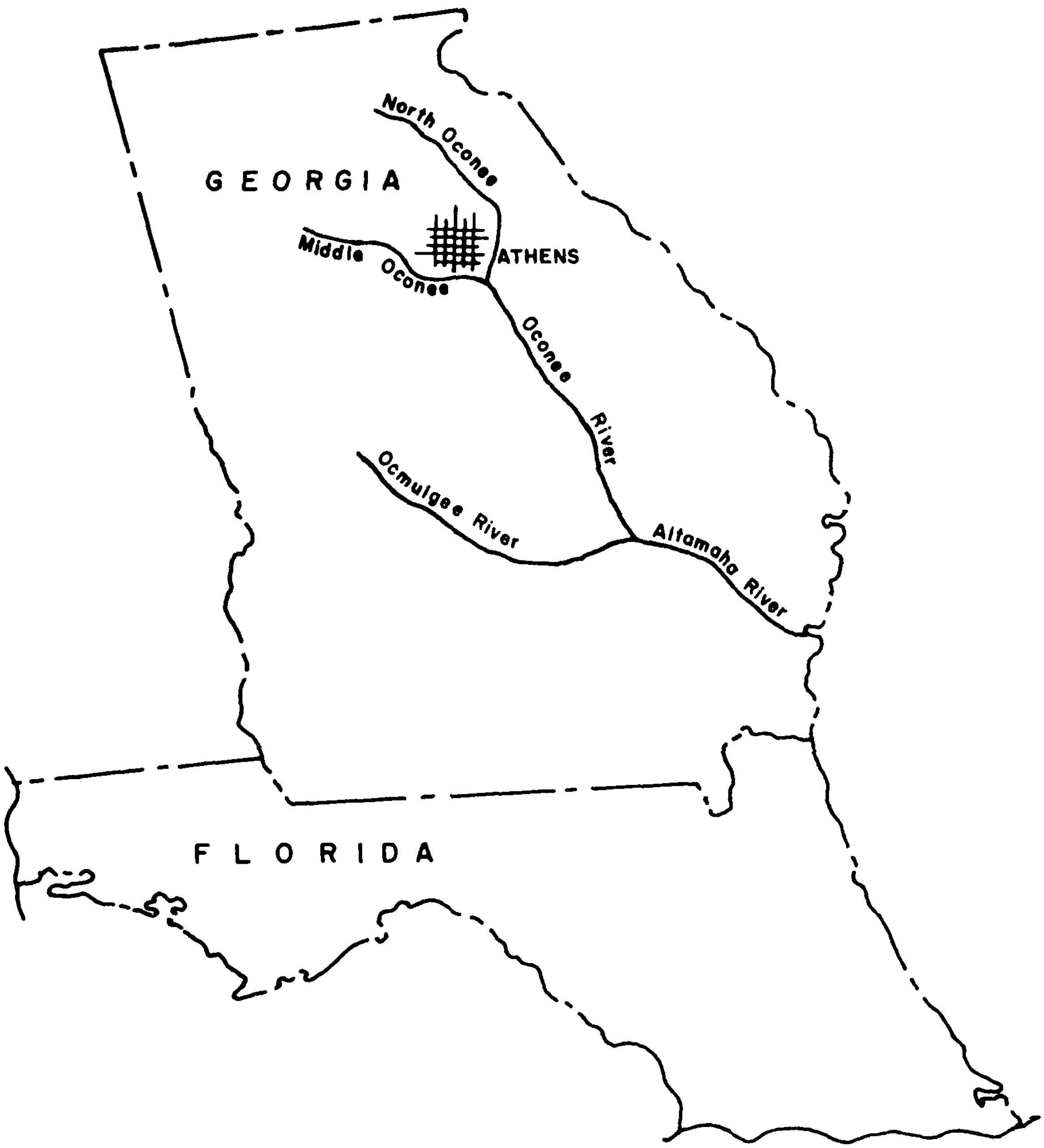

Fig. III-1. Location Map for Study Area

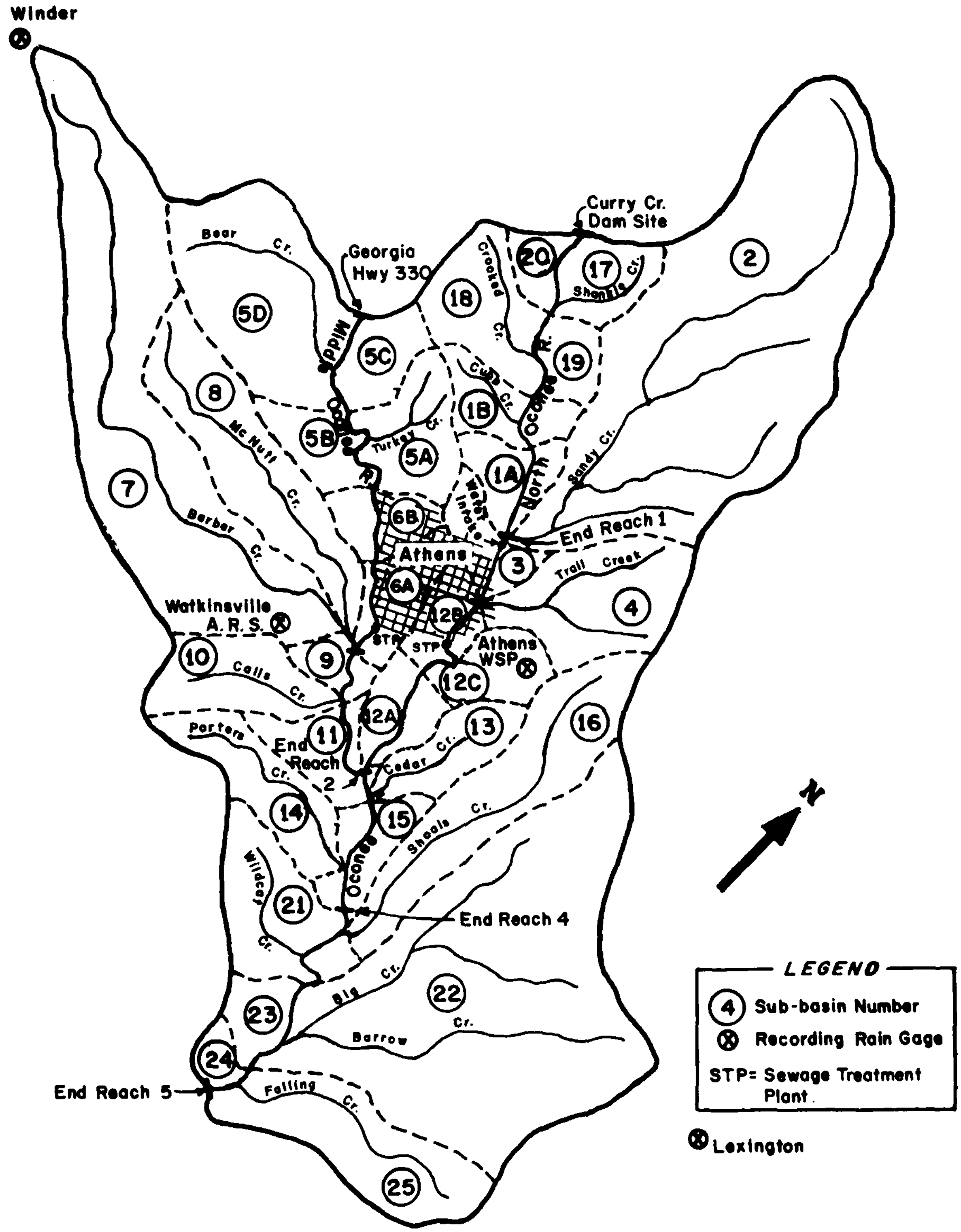

Figure III-2. Oconee River Study Area

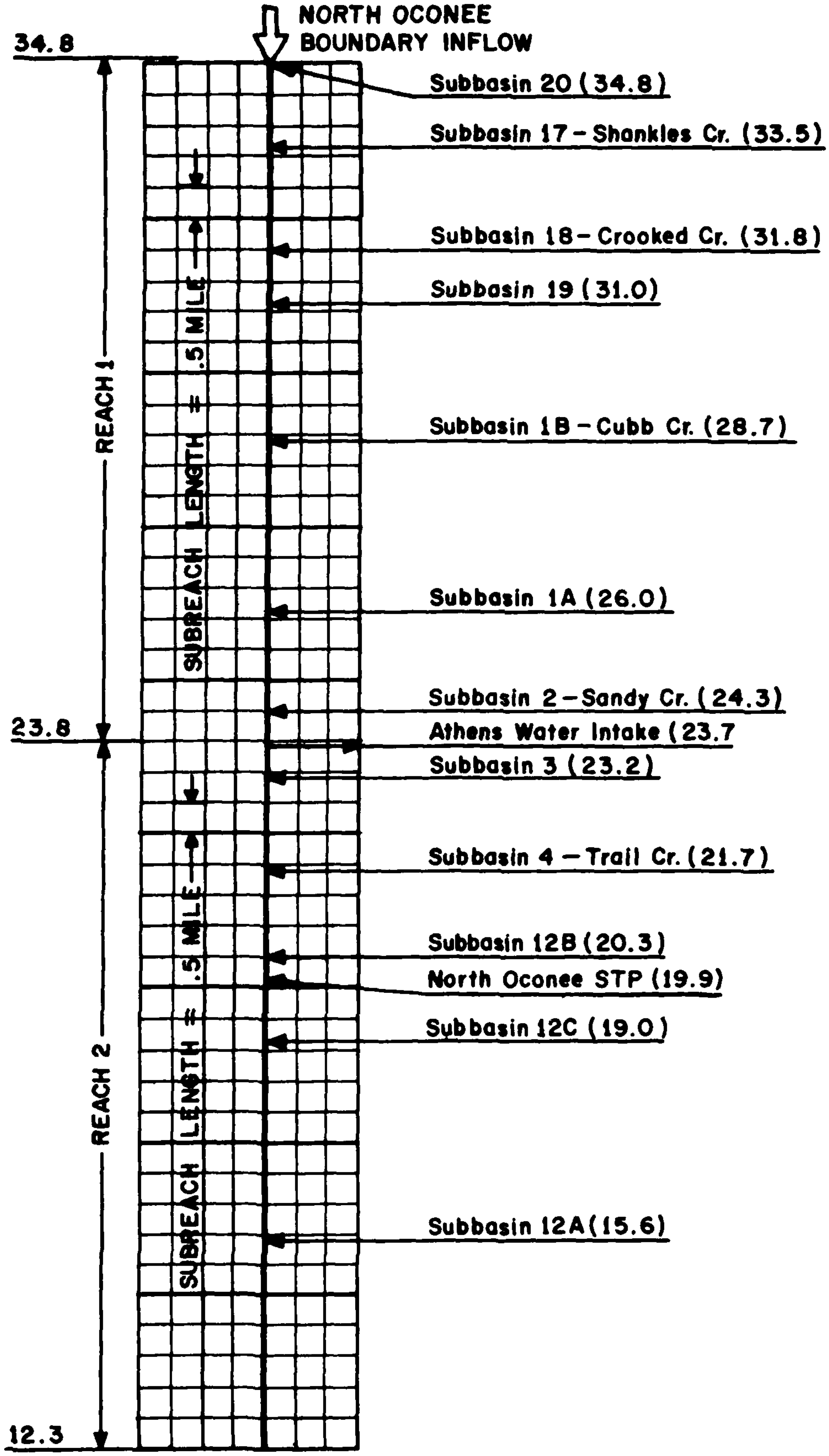

Fig III-3. Schematic of North Oconee River

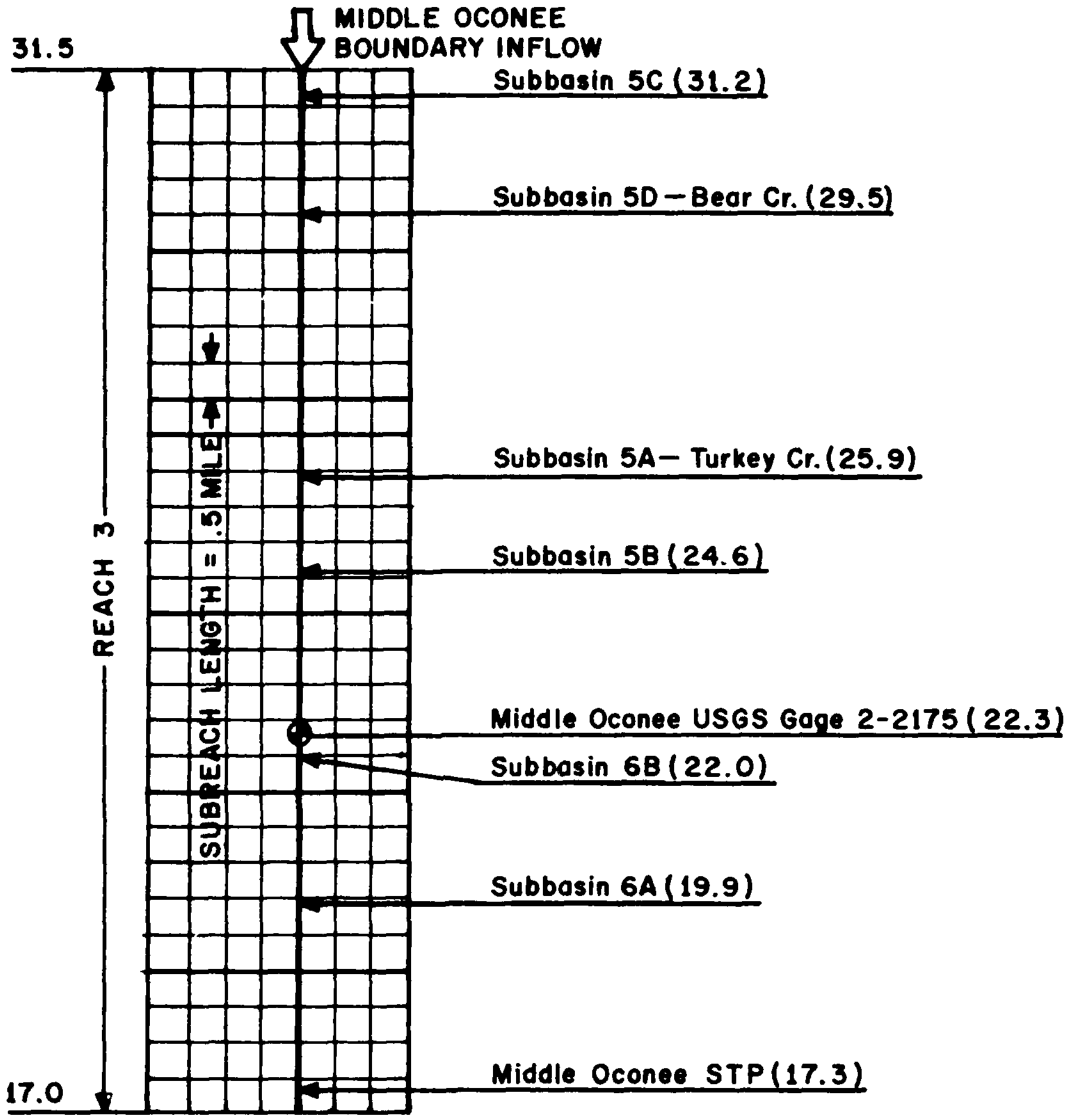

Fig. III-4. Schematic of Middle and Main Oconee River

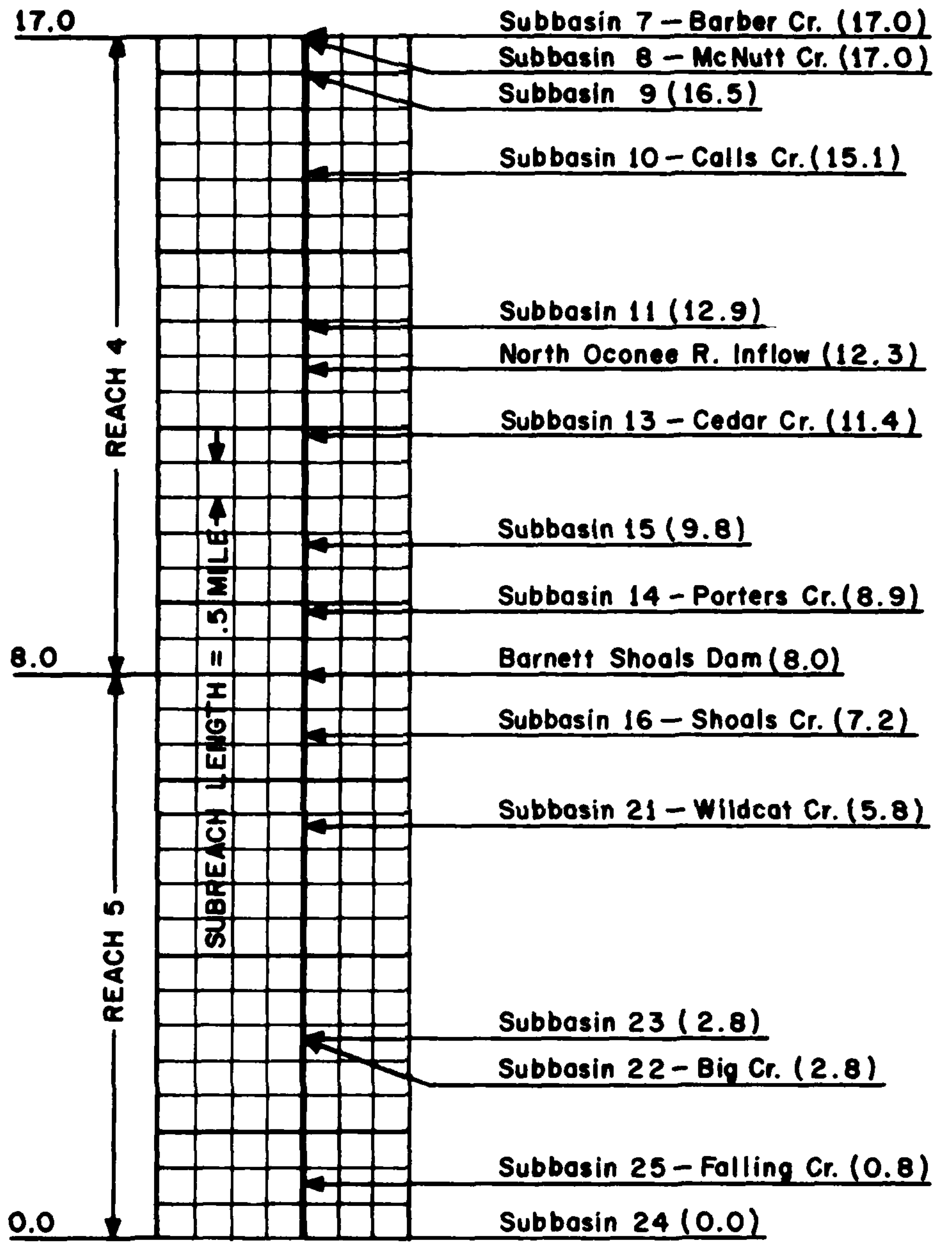

Fig. III-4. Schematic of Middle and Main Oconee River

METEOROLOGY

The weather data for the analysis were obtained from the National Weather Service using the Athens Municipal Airport Weather Station. A magnetic tape of hourly rainfall at five stations for the STORM model input and another tape of dry and wet bulb air temperature, barometric pressure, wind speed and cloud cover for the WQRRS model input were obtained from the Ashville, North Carolina office of the U.S. Weather Service. These input data were the easiest to obtain of all the required input data for either STORM or WQRRS. See Chapter IV for discussion of models.

LAND USE

Land use is one of the most important input variables for STORM. It is especially important in this study since one of the main objectives is to assess the impact of future development (as characterized by land use) on the water quality of the Oconee River. Land use for each STORM watershed was taken directly from output from HYDPAR (an HEC-developed utility program to calculate hydrologic parameters from a grid cell data bank). The specific land use categories that were used in this study are as follows:

Code No.	Designation
1	Developed Open Space (lawns, parks, golf courses, cemeteries and rights-of-way)
2	Low Density Residential
3	Medium Density Residential
4	High Density Residential
5	Agriculture (cultivated land, row crops, small grain)
6	Industrial
7	Commercial (strip and isolated commercial)
8	Pasture
9	High Density Commercial (downtown areas and shopping centers)
10	Institutional
11	Natural

Some alterations were made to a few of the land use categories. Low Density Residential and Medium Density Residential were combined into a single category. Hardwoods, pines, and wetlands were combined into a single category (Natural). Roads, land fills and water bodies were not simulated, however, the areas of each of these categories were subtracted from each watershed area. Table III-1 shows the land use for each STORM watershed for both existing and one alternative future (1990C).

TABLE III-1

LAND USE BY WATERSHED AND REACH

REACH NO.	SUB-BASIN NO.	AREA (ACRES)	LAND USE	EXIST %	1990C %
1	20	1870			
			Low Residential	1.1	1.1
			High Residential	0.0	0.0
			Commercial	0.0	0.0
			Industrial	0.0	0.0
			Pasture	25.5	25.5
			Natural	73.4	73.4
1	17	3700			
			Low Residential	2.3	2.3
			High Residential	0.0	0.0
			Commercial	0.0	0.0
			Industrial	0.0	0.0
			Pasture	38.4	38.4
			Natural	59.3	59.3
1	18	5620			
			Low Residential	1.8	1.8
			High Residential	0.0	0.0
			Commercial	0.0	0.0
			Industrial	0.0	0.0
			Agricultural	0.8	0.8
			Pasture	52.4	52.4
			Natural	45.0	45.0
1	19	2180			
			Low Residential	1.1	1.1
			Medium Residential	2.4	2.4
			Commercial	0.0	0.0
			Industrial	0.0	0.0
			Pasture	33.9	33.9
			Natural	62.6	62.6
1	1B	3741			
			Low-Medium Residential	2.3	6.2
			High Residential	0.4	0.4
			Commercial	0.3	0.6
			Industrial	0.0	0.0
			Agricultural	31.3	28.2
			Pasture	7.5	7.4
			Natural	57.8	54.8
			Open	0.4	0.6

NOTE: Water Area Is Included In Natural

TABLE III-1

LAND USE BY WATERSHED AND REACH

REACH NO.	SUB-BASIN NO.	AREA (ACRES)	LAND USE	EXIST %	1990C %
1	1A	2928			
			Low-Medium Residential	11.3	13.0
			High Residential	0.6	1.8
			Commercial	0.2	0.6
			Industrial	4.9	11.2
			Agricultural	9.7	6.3
			Pasture	11.1	7.9
			Institutional	0.2	2.8
			Natural	60.0	51.3
			Open	2.0	5.0
1	2	41254			
			Low-Medium Residential	2.1	3.1
			High Residential	0.1	0.2
			Commercial	0.1	0.2
			Industrial	0.0	0.0
			Pasture	41.8	41.7
			Institutional	0.1	0.1
			Natural	50.9	50.0
			Open	0.3	0.4
2	3	2272			
			Low-Medium Residential	30.9	33.1
			High Residential	5.9	4.4
			Commercial	4.3	4.6
			Industrial	14.4	15.1
			Agricultural	2.7	2.1
			Pasture	3.1	2.3
			High Commercial	1.0	1.0
			Institutional	1.6	1.5
			Natural	28.8	26.6
			Open	7.3	6.7
			Roads	0.0	2.6

TABLE III-1

LAND USE BY WATERSHED AND REACH

REACH NO.	SUB-BASIN NO.	AREA (ACRES)	LAND USE	EXIST %	1990C %
2	4	7915			
			Low-Medium Residential	20.0	21.5
			High Residential	2.6	2.6
			Commercial	1.8	2.0
			Industrial	1.5	15.3
			Agricultural	24.0	17.9
			Pasture	6.3	4.1
			High Commercial	0.0	0.5
			Institutional	0.7	1.0
			Natural	43.1	31.8
			Open	0.0	0.6
			Roads	0.0	2.9
2	12B	1756			
			Low-Medium Residential	18.6	18.6
			High Residential	4.9	6.0
			Commercial	4.2	3.8
			Industrial	0.0	0.0
			Agricultural	12.3	9.7
			Pasture	0.6	0.3
			High Commercial	3.5	3.5
			Institutional	34.6	34.1
			Natural	19.9	18.7
			Open	1.4	2.7
			Roads	0.0	2.7

TABLE III-1

LAND USE BY WATERSHED AND REACH

REACH NO.	SUB-BASIN NO.	AREA (ACRES)	LAND USE	EXIST %	1990C %
2	12C	2702			
			Low-Medium Residential	17.7	19.7
			High Residential	3.2	4.6
			Commercial	3.8	3.7
			Industrial	2.4	15.2
			Agricultural	8.2	5.3
			Pasture	10.0	5.5
			High Commercial	1.1	0.9
			Institutional	3.2	2.8
			Natural	39.0	31.5
			Open	11.4	7.2
			Roads	0.0	3.5
2	12A	3191			
			Low-Medium Residential	7.9	9.0
			High Residential	0.5	2.8
			Commercial	1.3	1.3
			Industrial	0.3	1.9
			Agricultural	11.8	9.0
			Pasture	5.1	3.7
			High Commercial	0.0	0.7
			Institutional	3.4	5.8
			Natural	65.9	60.5
			Open	3.8	4.8
			Roads	0.0	0.4
3	5C	3456			
			Low Residential	1.6	1.5
			High Residential	0.4	0.4
			Commercial	0.5	0.7
			Industrial	0.0	0.0
			Agricultural	16.6	16.5
			Pasture	4.0	4.0
			Natural	75.9	75.9
			Open	1.0	1.0

TABLE III-1

LAND USE BY WATERSHED AND REACH

REACH NO.	SUB-BASIN NO.	AREA (ACRES)	LAND USE	EXIST %	1990C %
3	5D	13020			
			Low Residential	2.3	2.2
			Medium Residential	1.2	1.2
			Commercial	0.3	0.3
			Industrial	0.0	0.0
			Agricultural	0.9	3.6
			Pasture	50.3	47.7
			Institutional	0.2	0.2
			Natural	43.9	43.9
			Open	0.9	0.9
3	5A	5723			
			Low-Medium Residential	18.3	25.7
			High Residential	1.7	2.3
			Commercial	0.6	1.1
			Industrial	1.1	1.0
			Agricultural	9.5	8.9
			Pasture	3.9	3.6
			High Commercial	0.2	0.8
			Institutional	0.6	1.7
			Natural	62.8	51.9
			Open	1.3	3.1
3	5B	3385			
			Low-Medium Residential	8.1	7.7
			High Residential	0.9	1.1
			Commercial	1.1	1.7
			Industrial	0.0	1.0
			Agricultural	17.5	16.8
			Pasture	4.7	4.7
			High Commercial	0.2	0.1
			Natural	67.4	66.8
			Open	0.1	0.1
3	6B	2658			
			Low-Medium Residential	23.9	32.0
			High Residential	5.4	9.3
			Commercial	7.2	7.3
			Industrial	0.0	0.0
			Agricultural	0.9	0.6
			Pasture	3.0	2.7
			High Commercial	1.7	1.7
			Institutional	2.7	3.1
			Natural	53.4	40.8
			Open	1.8	2.6

TABLE III-1

LAND USE BY WATERSHED AND REACH

REACH NO.	SUB-BASIN NO.	AREA (ACRES)	LAND USE	EXIST %	1990C %
3	6A	3443			
			Low-Medium Residential	47.6	49.5
			High Residential	2.4	3.2
			Commercial	5.9	5.9
			Industrial	0.0	0.0
			Agricultural	1.9	0.9
			Pasture	4.9	3.7
			High Commercial	1.7	1.7
			Institutional	3.0	2.8
			Natural	32.0	29.5
			Open	0.6	1.2
			Roads	0.0	1.6
3	7	27410			
			Low Residential	3.0	2.8
			Medium Residential	0.8	1.5
			Commercial	0.1	0.2
			Industrial	0.0	0.2
			Agricultural	16.0	15.4
			Pasture	37.1	37.3
			Institutional	0.1	0.2
			Natural	42.8	42.3
			Open	0.1	0.0
4	8	10260			
			Low-Medium Residential	13.1	15.2
			High Residential	0.8	1.4
			Commercial	1.1	1.2
			Industrial	0.0	0.0
			Agricultural	16.6	14.7
			Pasture	24.8	25.5
			High Commercial	0.0	0.1
			Institutional	0.2	0.5
			Natural	43.0	40.5
			Open	0.4	0.7
			Roads	0.0	0.2

TABLE III-1

LAND USE BY WATERSHED AND REACH

REACH NO.	SUB-BASIN NO.	AREA (ACRES)	LAND USE	EXIST %	1990C %
4	9	1290			
			Low Residential	0.8	0.8
			Medium Residential	8.3	7.8
			Commercial	1.2	1.5
			Industrial	0.0	0.0
			High Residential	0.0	3.4
			Agricultural	20.6	17.8
			Pasture	5.2	4.2
			Institutional	0.0	1.8
			Roads	0.0	2.5
			Natural	63.9	60.3
4	10	5946			
			Low Residential	0.5	0.5
			Medium Residential	7.2	9.7
			Commercial	0.7	0.8
			Industrial	0.4	0.4
			Agricultural	36.9	34.7
			Pasture	1.7	1.7
			High Commercial	0.0	0.1
			Institutional	1.3	1.6
			Roads	0.0	0.4
			Natural	51.3	50.1
4	11	3460			
			Low Residential	1.5	1.5
			Medium Residential	0.1	0.6
			Commercial	0.4	0.4
			Industrial	0.8	2.3
			Agricultural	10.7	9.8
			Pasture	13.2	12.9
			Institutional	0.1	1.0
			Natural	73.2	71.4
4	13	3428			
			Low-Medium Residential	20.6	32.1
			High Residential	1.3	2.7
			Commercial	0.2	0.5
			Industrial	0.0	2.8
			Agricultural	12.4	8.5
			Pasture	8.3	7.0
			High Commercial	0.0	0.2
			Institutional	1.5	2.3
			Natural	55.7	43.1
			Open	0.0	1.0

TABLE III-1

LAND USE BY WATERSHED AND REACH

REACH NO.	SUB-BASIN NO.	AREA (ACRES)	LAND USE	EXIST %	1990C %
4	15	3060			
			Low Residential	2.7	2.2
			Medium Residential	2.5	6.5
			Commercial	0.0	0.1
			Industrial	0.0	0.0
			Agricultural	7.4	7.0
			Pasture	7.6	7.5
			Natural	79.8	76.6
4	14	5021			
			Low Residential	1.2	1.2
			Medium Residential	2.6	3.2
			Commercial	0.7	0.8
			Industrial	1.1	1.5
			Agricultural	38.1	37.8
			Pasture	15.8	15.4
			Institutional	0.3	0.3
			Natural	40.2	39.9
5	16	11259			
			Low-Medium Residential	6.0	7.6
			High Residential	0.5	2.0
			Commercial	0.3	0.7
			Industrial	0.0	3.6
			Agricultural	30.4	27.9
			Pasture	5.7	5.1
			Institutional	0.1	0.9
			Natural	56.6	51.8
			Open	0.4	0.4
5	21	6930			
			Low Residential	0.4	0.4
			High Residential	0.0	0.0
			Commercial	0.0	0.0
			Industrial	0.0	0.0
			Pasture	48.7	48.7
			Natural	50.9	50.9
5	23	2580			
			Low Residential	0.0	0.0
			High Residential	0.0	0.0
			Commercial	0.0	0.0
			Industrial	0.0	0.0
			Agricultural	0.5	0.5
			Pasture	83.1	83.1
			Natural	16.4	16.4

TABLE III-1

LAND USE BY WATERSHED AND REACH

REACH NO.	SUB-BASIN NO.	AREA (ACRES)	LAND USE	EXIST %	1990C %
5	22	39550			
			Low Residential	1.0	1.0
			Medium Residential	0.2	0.2
			Commercial	0.0	0.0
			Industrial	0.0	0.0
			Agricultural	0.1	0.1
			Pasture	23.9	23.9
			Natural	74.8	74.8
5	25	9880			
			Low Residential	0.0	0.0
			High Residential	0.0	0.0
			Commercial	0.0	0.0
			Industrial	0.0	0.0
			Pasture	15.1	15.1
			Natural	84.9	84.9
5	24	1320			
			Low Residential	0.0	0.0
			High Residential	0.0	0.0
			Commercial	0.0	0.0
			Industrial	0.0	0.0
			Pasture	86.7	86.7
			Natural	13.3	13.3

RIVER GEOMETRY

Cross section data at irregular intervals along the entire stream system were provided by the Savannah District. The data were provided in a format for input to computer program HEC-2, Water Surface Profiles [3]. HEC-2 output provided information on energy grade line elevations which is a required input to WQRRS. More importantly, these same cross sections are input to computer program GEDA, Geometric Elements from Cross Section Coordinates [4]. GEDA provides output of vertically layered geometric data (i.e., cross section area, top width, hydraulic radius, composite Manning's n, etc.) at regularly spaced nodal points (e.g., one half mile apart), as required by WQRRS.

The preparation of geometric data for the WQRRS model is relatively automatic once the basic data of station-elevation coordinate points have been obtained either from field surveys or from contour maps.

HYDROLOGY

The Oconee basin was found to have little available hydrologic data. For the desired watershed modeling purposes, hydrologic data can be considered virtually non-existent. This serious lack of data required numerous assumptions. The accuracy of these assumptions cannot be evaluated except that the results did not seem unreasonable in terms of general hydrologic engineering judgment.

Only one USGS stage gage with hourly flow records was in operation during the selected study period, 1970. This gage is located at river mile 22.3 on the Middle Oconee River. To obtain the inflow across the study boundaries on the Middle and North Oconee Rivers (i.e., river mile 31.5 and 34.8 respectively), the hourly flow rate at the USGS gage was multiplied by the ratio of drainage area above the gage to that above each boundary.

Modified Puls routing criteria for the North, Middle and Main Oconee Rivers were provided by the Savannah District for selected control points. These data were linearly interpolated to obtain criteria at each load point (i.e., tributary inflows, sewage treatment plant effluents, and withdrawal locations). These data are shown in Table III-2.

TABLE III-2
MODIFIED PULS ROUTING CRITERIA

NORTH OCONEE RIVER

RIVER MILE	STORAGE (AF)	OUTFLOW (cfs)	RIVER MILE	STORAGE (AF)	OUTFLOW (cfs)
33.5-34.8	16	180	23.2-23.7	136	5282
	25	360		253	10600
	112	1800		289	13921
31.8-33.5	27	180	21.7-23.2	206	5282
	42	360		340	10600
	247	1800		425	13921
31.0-31.8	14	180	20.3-21.7	65	5282
	22	360		125	10600
	119	1800		163	13921
28.7-31.0	35	180	19.9-20.3	35	5312
	56	360		67	10900
	352	1800		85	14338
26.0-28.7	55	180	19.0-19.9	63	5312
	81	360		123	10900
	246	1800		155	14338
24.3-26.0	27	180	15.6-19.0	440	5312
	42	360		786	10900
	174	1800		995	14338
23.8-24.3	136	180	12.3-15.6	435	5312
	253	360		804	10900
	289	1800		1039	14338
23.7-23.8	30	5282			
	57	10600			
	65	13921			

TABLE III-2
MODIFIED PULS ROUTING CRITERIA

MIDDLE AND MAIN OCONEE RIVER

RIVER MILE	STORAGE (AF)	OUTFLOW (cfs)	RIVER MILE	STORAGE (AF)	OUTFLOW (cfs)
31.2-31.5	5	270	16.5-17.0	52	7100
	7	525		100	13500
	17	2700		122	17000
29.5-31.2	521	7100	15.1-16.5	407	7100
	829	13500		785	13500
	964	17000		961	17000
25.9-29.5	1148	7100	12.9-15.1	501	7100
	2397	13500		961	13500
	2937	17000		1391	17000
24.6-25.9	145	7100	12.3-12.9	50	7100
	279	13500		95	13500
	361	17000		120	17000
22.0-24.6	380	7100	11.4-12.3	353	8675
	636	13500		654	19300
	784	17000		819	25222
19.9-22.0	395	7100	9.8-11.4	564	8675
	731	13500		1173	19300
	885	17000		1462	25222
17.3-19.9	571	7100	8.9-9.8	214	8675
	1034	13500		364	19300
	1247	17000		433	25222
17.0-17.3	52	7100	8.0-8.9	133	8675
	100	13500		206	19300
	122	17000		235	25222

TABLE III-2
MODIFIED PULS ROUTING CRITERIA

MIDDLE AND MAIN OCONEE RIVER

RIVER MILE	STORAGE (AF)	OUTFLOW (cfs)	RIVER MILE	STORAGE (AF)	OUTFLOW (cfs)
7.2-8.0	398	8675	0.8-2.8	359	8675
	777	19300		1031	19300
	957	25222		1249	25222
5.8-7.2	734	8675	0.0-0.8	360	8675
	1318	19300		983	19300
	1630	25222		1248	25222
2.8-5.8	571	8675			
	1440	19300			
	1742	25222			

WATER QUALITY

The Oconee basin was found to have little available water quality data of practical use to this study. It was originally thought that adequate water quality data were available to calibrate the water quality simulation models, STORM and WQRRS. This serious lack of data required numerous assumptions which could not be verified with field data. The only evaluation that could be made was that the results appeared reasonable in the light of other experience.

Since 1968, water quality data have been collected at the USGS stage gage on the Middle Oconee River (i.e., river mile 22.3) and since 1974 at the Athens water intake on the North Oconee River. The data from these two sampling locations together with the data from Smith [5], Appendix A, were used to estimate base flow quality data for the boundary condition and the tributaries. The boundary quality condition was held constant during storm events and the tributary inflow quantity and quality was obtained from the STORM model output.

IV MODELING CONCEPTS APPLIED

STORM

The Storage, Treatment, Overflow Runoff Model (STORM) is a continuous simulation model designed to be used in metropolitan master planning studies for evaluating storage and treatment capacities required to reduce overflows. Pollutograph (pollutant mass-emmission rates) loadings can also be computed for use in a receiving water assessment model.

Since STORM is intended for use in planning studies or for screening alternatives, some of its analytical techniques are necessarily simplified. For example, the two procedures used to compute the quantity of runoff are the coefficient method and the United States Soil Conservation Service (SCS) method. In the coefficient method, a single land-use weighted runoff coefficient is applied to each hour of rainfall excess above depression storage to compute runoff. The runoff coefficient is a function of only the respective runoff coefficients for the pervious and impervious areas of the watershed. Antecedent conditions and rainfall intensity are not taken into account using this method.

The SCS runoff curve number technique is considered to be conceptually more correct than the coefficient method. The SCS curve consists of a nonlinear relationship between accumulated rainfall and accumulated runoff. Since STORM requires a continuous analysis, a procedure has been added that computes the curve number for each event based on the number of dry hours since the previous runoff event and prior evapotranspiration and percolation. Unit hydrographs can be used to transform the surface runoff excesses into basin outflow hydrographs.

Loads and concentrations for six basic water quality parameters are computed. These are suspended and settleable solids, biochemical oxygen demand, total nitrogen, total orthophosphate, and total coliforms. Urban and nonurban areas may be described by up to 20 land uses. Other features of STORM are the capabilities to compute snowfall/snowmelt, dry-weather flow quantity and quality, and land surface erosion.

STORM has a unique advantage of being able to accept discharge hydrographs as input for computing the associated wash-off of constituents.

WQRRS

The Water Quality for River-Reservoir Systems (WQRRS) model has capability for ecologic evaluation of rivers or reservoirs. It is a dynamic continuous simulation model. The model consists of three separate but integrable modules. These are the reservoir module, the stream hydraulic module, and the stream quality module. Since each module is a stand-alone program, the reservoir, the streamflow routing, or the stream water quality module may be executed, analyzed and interpreted independently. The three computer programs may also be integrated into a complete river basin water quality analysis.

The reservoir section of the program estimates the water quality condition in deep impoundments that can be represented as one-dimensional systems in which the isotherms, or contours of any parameter, are horizontal. This approximation is generally satisfactory in lakes with long residence times. However, the approximation is less satisfactory in shallow impoundments or those that have a rapid flow-through time. Systems that have a rapid flow-through time are often fully mixed and can be treated as slowly moving streams using the stream section of the model.

The stream hydraulic section of the model includes six hydraulic calculation options. This module is capable of handling hydraulic behavior for both the "gradually varied" steady and unsteady flow regimes. Peak flows from storm water runoff or irregular hydropower releases can be accurately represented.

In the stream quality module, the rate of transport of quality parameters can be accurately represented and peak pollutant loads into the steady or unsteady hydraulic environment can be simulated. The stream portions of WQRRS have two automatic interface options for use with the STORM model.

V MODELING RESULTS

STORM RUNOFF QUANTITY AND QUALITY

The approach used to calculate storm runoff was to sub-divide the total study area into a number of individual watersheds and apply STORM to each. Criteria affecting the number of watersheds include the degree of refinement in discrete points along the receiving water body where individual calculations are to be made and manageability of data for the entire study. A total of 32 individual watersheds were identified and are shown on Figure III-2. Several of the watersheds in the Savannah District Data Bank were further subdivided so as to provide better definition of quality in the urbanized river reaches.

The first major effort in the STORM application was to assemble and edit hourly precipitation data. Five recording rain gages exist in or near the study area; the locations are shown in Figure III-2. Only the Athens gage (Station No. 0435) was a Class I U.S. Weather Service gage. The other four gages are supplemental locations and, as a result, the data have not been corrected for gage failures. Numerous places existed on the tapes where the gage had failed and the accumulated precipitation was shown in the first hour of resumption of recording. A special editor program was written to locate these gage failures and redistribute the precipitation to the hours in which they occurred. The precipitation was distributed evenly over the hours of gage failure.

The continuous precipitation histories (1948-72) were used to assess the average annual land surface erosion for both existing and future conditions. The single year 1970 was used for storm water simulations since it was the month of October 1970 that was studied in the receiving water analysis using WQRRS.

No data existed with which to calibrate the rainfall-runoff calculations in STORM for the Oconee study. The various soil moisture characteristics required for the SCS runoff method were estimated. The October percentage runoff for several nearby gages served as a guide. The tributary flows, when combined and routed to a gage near the downstream study boundary showed fair agreement with the observed, however no check could be made on individual tributary flows. The estimated runoff characteristics are shown below:

LAND USE	Soil Moisture at Saturation (SMAX), Inches	Max Initial Abstraction Capacity (DEPR), Inches
Open	14.40	2.88
Low D. Residential	11.70	1.17
Medium D. Residential	7.54	0.11
Low-Medium D. Residential	9.62	0.18
High D. Residential	4.28	0.06
Agricultural	7.54	1.51
Industrial	3.33	0.05
Commercial	2.34	0.04
Pasture	10.00	2.00
High D. Commercial	1.24	0.02
Institutional	3.16	0.05
Roads	4.70	0.07
Natural	15.00	3.00

No data existed with which to calibrate the runoff quality calculations in STORM for the Oconee Study. The various pollutant accumulation rates required to regulate the quality were estimated based on data from the literature [6,7]. Adjustments were made during calibration so that tributary storm water concentrations for existing conditions did not greatly exceed certain measured concentrations in the river. Storm water quality calculations were not calibrated directly to the river concentration for three reasons: 1) minimal data existed, 2) the data consisted of grab samples taken at infrequent intervals, and 3) there were no indications that the measurements were taken during periods of tributary storm runoff. Table V-1 shows the adopted pollutant accumulation rates.

TABLE V-1

Pollutant Accumulation Rates (lb/ac/day)

Land Use	Susp Solids	Setl Solids	BOD_5	N	PO_4	Coliform 10^9MPN/ac/day
Low Res	.12	.09	.002	.0002	.0004	.60
LM Res	.43	.16	.004	.0008	.0006	.62
Med Res	.45	.18	.004	.0008	.0006	.63
High Res	3.10	.99	.006	.0006	.0020	4.9
Coml	3.60	1.35	.022	.0060	.0040	4.5
Ind	6.00	2.25	.020	.0055	.0030	5.0
Agr	7.20	2.70	.001	.0012	.00002	.25
Pasture	.24	.10	.001	.0002	.0002	.50
Hi Coml	3.90	1.44	.016	.0065	.0048	5.0
Instl	3.10	1.17	.006	.0006	.0020	6.0
Natural	.10	.04	.001	.0001	.000002	.0005
Open	.24	.08	.001	.0002	.0002	.50

Dry weather sewage flow was simulated for those basins with significant urban land use. Dry weather flow option three was used since it allows computations to be made on the basis of land use and population. The coefficients used are shown in Table V-2. Domestic, Commercial and Industrial coefficients were taken from References 8 and 9, with some minor modifications. Pipe infiltration coefficients were estimated so that the quality concentrations did not exceed those for baseflow from non-urban subbasins. The coefficients were assumed to remain constant for the alternative future.

TABLE V-2

Dry-Weather Flow Coefficients

	Domestic	Commercial	Industrial	Infiltration
Flow (mgd/acre)	100 1/	.03	.01	.0005
Suspended Solids (lb/day/ac)	1.3 2/	1.9	2.6	.08
Settleable Solids (lb/day/ac)	.22 2/	.33	.44	.008
BOD_5 (lb/day/ac)	.20 2/	.30	.40	.002
N (lb/day/ac)	.04 2/	.05	.06	.0012
PO_4 (lb/day/ac)	.01 2/	.012	.02	.0004
Coliform (10^9MPN/day/ac)	.64 3/	.86	.86	.0125

1/ gallons/day/capita for Domestic
2/ pounds/day/capita for Domestic
3/ 10^9 MPN/day/capita for Domestic

Since the dry weather flow algorithm in STORM calculates loads and concentrations of raw waste water, reductions must be made to account for treatment that exists in the study area. An assumption was made that the level of treatment remains constant for the alternative future. The following removal efficiencies were used for each subbasin having dry weather flow.

Treatment Efficiencies Used in STORM
(percent)

Suspended Solids	87	BOD_5	87	Orthophosphate	80
Settleable Solids	87	Nitrogen	80	Coliform	92

Table V-3 shows predicted tributary loads in pounds for the 10 month period of January 1970 through October 1970. While these loads cannot be used as an evaluation objective in themselves, they are useful to distinguish trends. In every case the predicted loads for 1990C land use pattern exceeded those for existing conditions. These loads were not used for the instream analysis. The receiving water analysis was accomplished using hourly loads and concentrations for the month of October 1970.

Storm water quantity and quality were also simulated for the Pendergrass detailed study area, however since a receiving water analysis was not performed there was no need to predict individual subbasin loadings. Table V-4 summarizes the predicted storm runoff quality loadings for the Pendergrass detailed study area.

TABLE V-3

Predicted Washoff Of Pollutants
January through October 1970
For Athens, Georgia

Sub-Basin	Land Use Condition	Suspended (lbs)	Settleable (lbs)	BOD_5 (lbs)	N (lbs)	PO_4 (lbs)	Coliform (10^9 MPN)
1A	Exist	130,594	16,178	8,735	2,163	689	234,900
	1990C	290,679	37,227	19,584	4,850	1,619	591,357
1B	Exist	225,891	26,722	13,743	3,501	1,013	70,307
	1990C	239,653	29,060	14,757	3,742	1,097	98,696
2	Exist	543,552	62,294	30,069	8,914	3,361	939,384
	1990C	568,482	65,946	32,177	9,414	3,563	1,089,263
3	Exist	531,935	81,585	39,601	9,839	3,554	781,667
	1990C	590,241	93,138	43,651	11,450	3,826	838,779
4	Exist	1,099,708	150,069	77,585	20,118	6,068	846,244
	1990C	2,477,564	376,509	170,838	43,176	13,253	2,365,152
5A	Exist	146,176	20,284	13,576	3,989	1,340	303,512
	1990C	241,125	33,292	22,600	5,905	1,821	569,130
5B	Exist	65,205	8,262	4,017	1,007	296	69,380
	1990C	76,110	9,786	4,885	1,223	367	109,742
5C	Exist	35,174	4,032	1,892	466	126	19,669
	1990C	36,089	4,18[illegible]	1,962	485	134	22,030
5D	Exist	68,370	7,402	3,479	1,471	214	216,959
	1990C	90,704	10,043	4,861	1,829	315	213,361
6A	Exist	227,543	30,400	21,549	5,948	1,966	716,565
	1990C	251,100	33,969	23,928	6,189	2,074	807,381
6B	Exist	124,060	16,345	11,827	3,001	1,329	548,663
	1990C	196,694	25,417	18,193	4,961	1,689	728,025
7	Exist	474,924	54,318	26,007	7,206	1,790	398,404
	1990C	502,582	58,427	27,647	7,666	1,909	484,140
8	Exist	313,924	43,386	27,205	7,680	2,481	407,848
	1990C	388,010	55,410	36,551	9,771	2,811	586,679
9	Exist	31,159	3,562	1,850	455	125	23,925
	1990C	50,177	6,204	3,290	809	256	110,982

TABLE V-3 (Con't)

Predicted Washoff Of Pollutants
January through October 1970
For Athens, Georgia

Sub Basin	Land Use Condition	Suspended (lbs)	Settleable (lbs)	BOD_5 (lbs)	N (lbs)	PO_4 (lbs)	Coliform (10^9 MPN)
10	Exist	289,780	37,070	17,960	4,613	1,344	172,652
	1990C	333,103	42,923	20,516	5,268	1,565	246,885
11	Exist	32,252	3,586	1,516	364	102	30,428
	1990C	41,906	5,182	5,482	604	185	84,808
12A	Exist	117,069	14,402	7,755	1,898	605	226,020
	1990C	207,271	25,616	13,865	3,401	1,161	504,939
12B	Exist	751,269	145,068	49,750	12,276	3,920	1,089,028
	1990C	735,841	144,459	48,679	11,989	3,857	1,144,164
12C	Exist	229,663	30,845	17,105	4,239	1,216	439,079
	1990C	686,401	102,465	48,927	12,159	4,272	1,001,348
13	Exist	106,697	14,890	9,531	2,934	445	175,192
	1990C	200,750	27,880	19,367	5,209	1,792	458,203
14	Exist	237,387	29,749	14,208	3,649	1,060	128,786
	1990C	251,051	31,778	15,142	3,893	1,143	149,505
15	Exist	16,468	1,982	873	197	52	14,138
	1990C	23,865	2,950	1,291	297	85	27,180
16	Exist	235,374	30,904	13,910	4,540	928	171,134
	1990C	508,469	64,824	33,360	9,468	2,571	872,182

TABLE V-4

Storm Runoff Quality Loadings
Pendergrass Study Area Jan - Oct 1970

	Suspended Solids (lb)	Settleable Solids (lb)	BOD_5 (lb)	Nitrogen (lb)	PO_4 (lb)	Coliform (10^9 MPN)
Existing	195,244	23,730	12,808	3,099	933	214,766
1990 B	1,113,700	142,800	74,755	18,467	6,234	2,139,334

LAND SURFACE EROSION

Land surface erosion yield was computed by the Universal Soil Loss Equation. The equation, as implemented in STORM, requires a continuous hourly precipitation record to serve as the prime mover in the analysis. The period of January 1948-December 1972 at the Athens gage for the Athens area (Winder gage for Pendergrass) was used for both existing and future conditions. The K, LS, C, P and SDR terms in the equation are shown in Table V-5 [10, 11].

The average annual land surface erosion was computed for the period of record and from several trial runs it was determined that, for the period of January 1, 1961 to December 31, 1961 the land surface erosion approximated the average annual land surface erosion for the period of record. This shorter period was used in subsequent runs to calculate the average annual land surface erosion for the various subbasins in the Athens Study Area.

An important consideration in the land surface erosion analysis was the effect of exposed soil in areas under development. For each grid cell the land use for existing and future conditions were compared and the number of cells with changed land use were counted. It was then assumed that the change in land use will be uniformly distributed over the 15 year period 1976-1990. Therefore, the area under development for any one year is approximately 7% of the total change during the 15 years. For that area under development the factors representing the soil cover were modified to reflect denuded soil. Specifically, the Cover Factor and Erosion Control Factor were set to 100.

TABLE V-5

Soil Erodibility Factors

SOIL NO.	SOIL CODE	SERIES NAME	K	SOIL NO.	SOIL CODE	SERIES NAME	K
2	Ak			39	Ln	Louisburg	0.24
3	Am			41	Mc		
4	An	Appling	0.32	43	Mg	Madison	0.32
5	As			44	Mi	Madison	0.32
6	Ax	Appling	0.32	45	Mm	Madison	0.32
7	Bfs	Buncombe	0.17		Mm	Louisa	0.28
8	Ca			47	My	Musella	0.28
9	Cb	Cecil	0.32	48	Pa		
10	Ce			49	Pf	Pacolet	0.32
11	Cf			50	Pg	Pacolet	0.32
12	Ci	Colfax		51	Ph	Pacolet	0.32
13	Coa	Congaree		52	Pi	Pacolet	0.32
14	Cob	Chewacla		54	Pt		
17	Cy			55	Rc		
18	CY	Cecil	0.32	56	Rok	Rock	0.00
19	CZ	Cecil	0.32	57	Tf		
21	Dh	Davidson	0.32	58	To		
22	Dq	Davidson	0.32	61	Wq		
23	EW			62	Wk	Worsham	
25	Ge			63	Wos	Wehadkee	
29	Gr			65	LD	Louisburg	0.25
31	Hc						
33	Hi						

NOTE: SOILS WITH NO "K" VALUE USED THE DEFAULT OF 0.32

TABLE V-5

Length for LS Factor

SLOPE %	LENGTH (ft)
0 - 2.00	200
2.01 - 6.00	275
6.01 - 10.00	175
10.01 - 15.00	75
15.01 - 25.00	50

Cover and Erosion Control Factors

Land Use	Cover Factor (C)	Erosion Control Factor % (P)
1. Open	1.3	95
2. Low Residential	0.3	85
3. Medium Residential	0.3	70
4. High Residential	0.3	60
5. Agricultural	40.0	95
6. Industrial	10.0	40
7. Commercial	1.2	20
8. Pasture	2.0	95
9. High Commercial	1.0	10
10. Institutional	10.0	40
11. Roads	5.0	60
12. Natural	0.3	95

TABLE V-5

Sediment Delivery Ratio (SDR)

WATERSHED NO.*	AREA, ac	SDR
1	6669	0.18
2	10444	0.16
3	2272	0.23
4	7915	0.17
5	7648	0.17
6	16301	0.14
7	6101	0.18
8	12164	0.16
9	6242	0.18
10	1290	0.25
11	5946	0.19
12	3460	0.21
13	3438	0.21
14	5039	0.19
15	3103	0.21
16	11253	0.16
Pendergrass	7067	0.17

*Savannah District Watershed Identification

All other factors in the soil loss equation remained the same as in the developed condition. The predicted land surface erosion for the Athens and Pendergrass study areas are shown in Tables V-6 and V-7.

Table V-6

Athens, Georgia

Average Annual Land Surface Erosion (tons)

Watershed No.*	Existing	1990 C
1	76900	72000
2	112000	115300
3	5000	6300
4	85000	83900
5	51100	55700
6	118700	306200
7	10100	16900
8	222700	219900
9	93100	88500
10	17900	17100
11	96800	93800
12	24500	24400
13	23500	23100
14	89000	67000
15	4800	5200
16	163100	157400

*Savannah District Watershed Identification

TABLE V-7

Average Annual
Land Surface Erosion
Pendergrass Area

Existing Land Use	105220 tons
Alternative B Land Use	94910 tons

RECEIVING WATER

Analysis of Existing Condition

The WQRRS model accepts input tributary conditions derived using the STORM model on each of the 32 subbasins (see Figures III-2, III-3 and III-4) draining into the portion of the Oconee River within the specified study boundaries and imposes these loadings on a base flow condition. The two sewage treatment plants and the Athens water intake are accounted for based on mean monthly data from the State of Georgia, except for unmeasured parameters which were then estimated from textbook average conditions [12]. These input data are shown in Table V-8. An accounting is made of the mass balance at each tributary location and the resulting mixture is transferred (i.e., routed) downstream to the next tributary location with the proper reactions and interactions being calculated according to the estimated travel time between tributaries and the input system coefficients shown in Table V-9.

The initial quality condition for selected locations is shown in Table V-10. The quality at all other locations is obtained by linear interpolation. The values shown for river mile 34.8 and 31.5 on the North Oconee and Middle Oconee respectively are also the base flow quality conditions which enter the study area at the upper boundaries.

The base flow condition on the tributaries during non-storm periods is dependent on the proportion of the drainage area having residental land use. Table V-11 shows the tributary base flow used as inflow to the Oconee during non-storm periods.

TABLE V-8

INPUT DATA FOR SEWAGE TREATMENT PLANTS AND WATER TREATMENT PLANTS FOR EXISTING AND ALTERNATIVE FUTURE C LAND USE

Parameter 1/	North Oconee STP(R.M. 19.9) Exist	North Oconee STP(R.M. 19.9) Alt.C	Middle Oconee STP(R.M. 17.3) Exist	Middle Oconee STP(R.M. 17.3) Alt.C	Athens Water Intake(R.M. 23.7) Exist	Athens Water Intake(R.M. 23.7) Alt.C
Q (cfs) 2/	10.1	15.3	3.25	5.0	16.6	24.9
Temperature (°C)	3/	3/	3/	3/		
DO (assumed)	0	0	0	0		
BOD5 4/	99	99	84	84		
Coliform (assumed) (MPN/100 ml)	200	200	200	200		
Detritus (25% of susp. solids)	8.25	8.25	7.25	7.25		
NH3 [5]	10	10	10	10		
NO3 [5]	20	20	20	20		
NO2 [5]	.05	.05	.05	.05		
PO4 [5]	12	12	12	12		
TDS	244	244	154	154		
Algae (assumed)	.001	.001	.001	.001		
Zooplankton (assumed)	.001	.001	.001	.001		
pH (units)	6.7	6.7	7.3	7.3		
Akalinity (assumed)	100	100	100	100		

1/ mg/l except as noted.

2/ Flow for Alternative C equals existing flow times estimated proportional increase in population.

3/ Water temperature equals mean daily air temperature minus 2°C [13] except during storm events when water temperature equals the hourly air temperature.

4/ Uncorrected for NH_3, NO_2 and Detritus oxygen demand [13].

TABLE V-9

INPUT SYSTEM COEFFICIENTS

REACTION RATE MULTIPLIER PARAMETERS

	CALIBRATION MAGNITUDES				CALIBRATION TEMPERATURES			
	K1	K2	K3	K4	T1	T2	T3	T4
ALGAE 1	.10	.98	.98	.10	5.0	22.0	25.0	34.0
ALGAE 2	.10	.98	.98	.10	10.0	28.0	30.0	40.0
ZOOPLANKTON	.10	.98	.98	.10	5.0	28.0	30.0	38.0
BENTHIC ANIMALS	.10	.98	.98	.10	5.0	22.0	25.0	33.0
FISH 1	.10	.98	.98	.10	5.0	20.0	20.0	25.0
FISH 2	.10	.98	.98	.10	10.0	27.0	30.0	38.0
FISH 3	.10	.98	.98	.10	5.0	22.0	30.0	36.0
BOD	.10	.98			4.0	30.0		
NH3-N	.10	.98			4.0	30.0		
NO2-N	.10	.98			4.0	30.0		
DETRITUS	.10	.98			4.0	30.0		

DECAY COEFFICIENTS, PER DAY	MAX VALUE
BOD	.100
NH3-N	.050
NO2-N	.200
DETRITUS	.001
COLIFORM (AT 20 DEG C)	.500

Q10 TEMPERATURE COEFFICIENT FOR COLIFORM 1.040

CHEMICAL COMPOSITIONS OF BIOTA

	C	N	P
ALGAE	.500	.090	.012
ZOOPLANKTON	.500	.090	.012
FISH	.500	.090	.012
BENTHOS	.500	.090	.012
DETRITUS	.500	.090	.012

DIGESTIVE EFFICIENCY OF BIOTA

ZOOPLANKTON	.700
FISH	.600
BENTHOS	.400

MORTALITY RATES, PER DAY	MAX VALUE
ZOOPLANKTON	.500E-02
FISH	.100E-02
BENTHOS	.100E-02

TABLE V-9 (cont'd)

RESPIRATION RATES, PER DAY	MAX VALUE
PHYTOPLANKTON	.500E-01
ZOOPLANKTON	.200E-01
FISH	.100E-02
BENTHOS	.100E-02

DETRITUS SETTLING, METERS/DAY	.15000

OTHER PHYTOPLANKTON DATA

SETTLING, METER/DAY	.15000	.15000
OXYGENATION FACTOR	1.600	
PREFERANCE	.670	.330
SELFSHADING PER MG/L/M	0	

MAXIMUM SPECIFIC GROWTH RATE, PER DAY

PHYTOPLANKTON, 2 GROUPS	.100E+01	.200E+01	
ZOOPLANKTON	.150E+00		
FISH, 3 GROUPS	.200E-01	.250E-01	.200E-01
BENTHOS	.200E-01		

HALF-SATURATION CONSTANTS OF ALGAE

	LIGHT	CO2	N	PO4
ALGAE 1	.003	.020	.200	.030
ALGAE 2	.005	.020	.100	.050

HALF-SATURATION CONSTANTS FOR ZOO, FISH AND BENTHO

ZOO GRAZE ON ALGAE	.550
FISH 1 GRAZE ON ZOO	.050
FISH 2 GRAZE ON ZOO	.050
FISH GRAZE ON BENTHOS	500.000
BENTHOS GRAZE ON SEDMT	50.000

STOICHIOMETRIC EQUIVALENCE OF CHEMICAL TRANSFORMATION

O2/NH3	3.500
O2/NO2	1.200
O2/DETRITUS	2.000
O2/BIOMASS	2.000
CO2/BOD	.200

TABLE V-10

INITIAL QUALITY CONDITION

Location	Parameter	Magnitude 1/	Source
North Oconee-RM 34.8	BOD5	.5	Smith [5]
	Detritus	5	
	Sediment (gm/m^2)	16	
	Benthos (gm/m^2)	.9	
	NH_3	.03	State of Georgia gage at Athens Intake, average 1974
	NO_3	.24	
	NO_2	.01	
	PO_4	.03	
	pH (pH units)	7.1	
	Alkalinity	36	
	Coliform (MPN/100 ml)	430	Athens Intake 10/24/74
	Temp. (°C)	f(air) 2/	Willey & Huff [13]
	DO	8	Assumed at 80% of DO_{sat} at 15°C
	TDS	100	Assumed
	Algae	.001	
	Zooplankton	.001	
	Fish 1 (Kg/mi)	10	Smith [5]
	Fish 2 (Kg/mi)	30	
	Fish 3 (Kg/mi)	40	

TABLE V-10 (cont'd)

INITIAL QUALITY CONDITION

Location	Parameter	Magnitude 1/	Source
North Oconee-RM 23.8	BOD5	.5	STORM Base Flow
	NH_3	.08	
	NO_3	.22	
	PO_4	.10	
	Coliform (MPN/100 ml)	660	
	All other parameters same as R.M. 34.8		
North Oconee-RM 20.3	All parameters same as R.M. 23.8		
North Oconee-RM 19.8	Detritus (gm/m^2)	5.5	Smith [5]
	Sediment (gm/m^2)	18.4	
	All other parameters same as R.M. 23.8		
North Oconee-RM 12.3	All parameters same as R.M. 19.8		

TABLE V-10 (cont'd)

INITIAL QUALITY CONDITION

Location	Parameter	Magnitude 1/	Source
Middle Oconee-RM 31.5	BOD5	.5	Smith [5]
	Detritus	5	
	Sediment (gm/m^2)	16	
	Benthos (gm/m^2)	.9	
	NH_3	.10	USGS gage on Middle Oconee NH_3: 2/09/70 $NO_3 + NO_2$: avg of 11/18/70 and 5/26/70 PO_4: 9/02/70 pH and Coliform: 11/18/70
	NO_3	.60	
	NO_2	.01	
	PO_4	.06	
	pH (pH units)	7.5	
	Coliform (MPN/100 ml)	930	
	Alkalinity	25	Alkalinity: avg of 9/02/70 and 11/18/70
	Temp. (°C)	f(air) 2/	
	DO	8	80% of DO_{sat} at 15°C
	TDS	100	Assumed
	Algae	.001	
	Zooplankton	.001	
	Fish 1 (kg/mi)	10	Smith [5]
	Fish 2 (kg/mi)	30	
	Fish 3 (kg/mi)	40	

TABLE V-10 (cont'd)

INITIAL QUALITY CONDITION

Location	Parameter	Magnitude 1/	Source
Middle Oconee-RM 17.5	BOD5	.5	STORM Base Flow
	NH_3	.08	
	NO_3	.22	
	PO_4	.10	
	Coliform	660	
	All other parameters same as R.M. 31.5		
Middle Oconee-RM 17.0	Detritus (gm/m^2)	5.5	Smith [5]
	Sediment (gm/m^2)	18.4	
	All other parameters same as R.M. 17.5		
Main Oconee-RM 0.0	All parameters are same as Middle Oconee R.M. 17.0		

1/ mg/l except as noted

2/ water temperature equals hourly air temperature during a storm and equals mean daily air temperature minus 2°C during non-storm periods [13].

TABLE V-11
TRIBUTARY BASE FLOW QUALITY DATA 1/
EXISTING LAND USE

	Sub-Basin	River Mile	Drainage Area (mi^2)	Population	Base Flow (cfs)	DO (mg/l)	BOD5 (mg/l)	Coliform (MPN/100ml)	Detritus (mg/l)	NH_3 (mg/l)	NO_3 (mg/l)	NO_2 (mg/l)	PO_4 (mg/l)	TDS (mg/l)	pH	Alkalinity (mg/l)
REACH NO. 1 - NORTH OCONEE RIVER (RIVER MILE 34.8 - 23.8)																
Upper	Limit	34.8	-----	----	2/	8.0	.5	430	5	.03	.24	.01	.03	100	7.1	36
	20	34.8	2.9	34	1.4	8.0	.5	660	5	.08	.22	.01	.1	100	7.1	36
	17	33.5	5.8	128	2.9	8.0	.5	660	5	.08	.22	.01	.1	100	7.1	36
	18	31.8	8.8	152	4.3	8.0	.5	660	5	.08	.22	.01	.1	100	7.1	36
	19	31.0	3.4	358	1.7	8.0	.5	660	5	.08	.22	.01	.1	100	7.1	36
	1B	28.7	5.8	688	2.9	8.0	.5	660	5	.08	.22	.01	.1	100	7.1	36
	1A	26.0	4.6	1951	2.3	8.0	.5	660	5	.08	.22	.01	.1	100	7.1	36
	2	24.3	64.5	4619	64.5	8.0	.5	660	5	.08	.22	.01	.1	100	7.1	36
REACH NO. 2 - NORTH OCONEE RIVER (RIVER MILE 23.8 - 12.3)																
(DWF)	3	23.2	3.6	6151	12.3	8.0	2.7	1150	5	.20	.60	.01	.2	100	7.1	36
(DWF)	4	21.7	12.4	11490	16.3	8.0	3.5	1540	5	.28	.82	.01	.3	100	7.1	36
(DWF)	12B	20.3	2.7	3308	5.3	8.0	3.1	1360	5	.25	.75	.01	.2	100	7.1	36
	STP	19.9	----	-----	10.1	0.0	99.0	200	8.25	10.0	20.0	.05	12.0	244	6.7	100
(DWF)	12C	19.0	3.6	3592	7.3	8.0	2.5	1100	5	.20	.60	.01	.2	100	7.1	36
	12A	15.6	5.0	1699	2.5	8.0	.5	660	5	.08	.22	.01	.1	100	7.1	36
REACH NO. 3 - MIDDLE OCONEE RIVER (RIVER MILE 31.5 - 17.0)																
Upper	Limit	31.5	----	--	3/	8.0	.5	930	5	.10	.60	.01	.06	100	7.5	25
	5C	31.2	5.4	293	2.7	8.0	.5	660	5	.08	.22	.01	.1	100	7.5	25
	5D	29.5	20.3	1416	10.1	8.0	.5	660	5	.08	.22	.01	.1	100	7.5	25
(DWF)	5A	25.9	8.9	7303	8.1	8.0	4.5	1940	5	.35	1.05	.01	.4	100	7.5	25
	5B	24.6	5.3	1928	2.6	8.0	.5	660	5	.08	.22	.01	.1	100	7.5	25
(DWF)	6B	22.0	4.2	6036	11.9	8.0	2.6	1120	5	.20	.60	.01	.2	100	7.5	25
(DWF)	6A	19.9	5.4	10824	13.8	8.0	3.9	1700	5	.30	.90	.01	.3	100	7.5	25
	STP	17.3	---	----	3.25	0.0	84	200	7.25	10.0	20.0	.05	12.0	154	7.3	100
	7	17.1	42.8	2591	21.2	8.0	.5	660	5	.08	.22	.01	.1	100	7.5	25

TABLE V-11 (Cont'd)
TRIBUTARY BASE FLOW QUALITY DATA 1/
EXISTING LAND USE

	Sub-Basin	River Mile	Drainage Area (mi^2)	Population	Base Flow (cfs)	DO (mg/l)	BOD5 (mg/l)	Coliform (MPN/100ml)	Detritus (mg/l)	NH_3 (mg/l)	NO_3 (mg/l)	NO_2 (mg/l)	PO_4 (mg/l)	TDS (mg/l)	pH	Alkalinity (mg/l)
REACH NO. 4 - MIDDLE AND MAIN OCONEE RIVER (RIVER MILE 17.0 - 8.9)																
DWF	8	17.0	16.0	7636	14.4	8.0	2.7	1160	5	.20	.60	.01	.2	100	7.5	25
	9	16.5	2.0	678	1.0	8.0	.5	660	5	.08	.22	.01	.1	100	7.5	25
	10	15.1	9.3	2699	4.6	8.0	.5	660	5	.08	.22	.01	.1	100	7.5	25
	11	12.9	5.4	97	2.7	8.0	.5	660	5	.08	.22	.01	.1	100	7.5	25
DWF	13	11.4	5.4	4892	3.7	8.0	6.4	2790	5	.50	1.50	.01	.5	100	7.5	25
	15	9.8	4.8	596	2.4	8.0	.5	660	5	.08	.22	.01	.1	100	7.5	25
	14	8.9	7.8	902	3.9	8.0	.5	660	5	.08	.22	.01	.1	100	7.5	25
REACH NO. 5 - MAIN OCONEE RIVER (RIVER MILE 8.0 - 0.0)																
	16	7.2	17.6	4391	8.7	8.0	.5	660	5	.08	.22	.01	.1	100	7.5	25
	21	5.8	10.8	42	5.4	8.0	.5	660	5	.08	.22	.01	.1	100	7.5	25
	23	2.8	4.0	0	2.0	8.0	.5	660	5	.08	.22	.01	.1	100	7.5	25
	22	2.8	61.8	1084	30.6	8.0	.5	660	5	.08	.22	.01	.1	100	7.5	25
	25	0.8	15.4	0	7.6	8.0	.5	660	5	.08	.22	.01	.1	100	7.5	25
	24	0.0	2.1	0	1.0	8.0	.5	660	5	.08	.22	.01	.1	100	7.5	25

1/ Water temperature during storms equals the hourly air temperature, but during non-storm events water temperature equals the mean daily air temperature minus 2°C.

2/ Inflow at upper limit on the North Oconee River is taken as 43% of gaged flow on Middle Oconee River at USGS gage 2-2175.

3/ Inflow at upper limit on the Middle Oconee River is taken as 90% of gaged flow on Middle Oconee River at USGS gage 2-2175.

The initial and base flow quality conditions are arbitrarily accepted base conditions since essentially no gaged data exists for the study period. All the final results must be interpreted relative to this base condition since most of the water quality calculations are non-linear (i.e., effect of saturation values and temperature corrections on all reaction rates).

Table V-12 shows an example of a statistical summary of the water quality condition at a random point along the river for existing land use. The critical values (i.e., maximum or minimum) for some of these parameters at various locations along the river have been plotted in Figures V-1 to V-6 to show a river water quality profile for the most critical condition occurring during the period simulated for dissolved oxygen (DO), ammonia (NH_3), nitrate (NO_3), phosphate (PO_4), log coliform bacteria and 5-day carbonaceous biochemical oxygen demand (BOD_5).

The existing water quality condition seems to meet all the Georgia State Water Quality Standards (i.e., Table V-13) except for coliform bacteria which may exceed the standards 5-10% of the time, from river mile 25 to 12.3 respectively on the North Oconee and throughout the study length of the Middle and Main Oconee about 10-16% of the time.

The impact on the water quality in the Oconee due to the various tributaries and sewage treatment plants is shown in Figures V-1 to V-6. Major point source impacts on the North Oconee River are summarized in Table V-14, and on the Middle and Main Oconee River in Table V-15.

Remarks in Tables V-14 and V-15 concerning nutrients having significant impact refer to the potential impact on algae production in non-turbid water. Unless significant improvement occurs in the turbidity of the Oconee River, this potential will be not be realized.

Sample graphical results of the simulations are shown in Appendix B.

TABLE V-12
WATER QUALITY AT RIVER MILE 11.5
EXISTING LAND USE

```
****************************************
 POST-PROCESSOR FOR WQRRS     APRIL 1976
HYDROLOGIC ENGINEERING CENTER  DAVIS, CA
****************************************

   OCONEE RIVER WATER QUALITY STUDY    **WQRRS STATISTICAL POST-PROCESSOR**
   REACH 4  MIDDLE OCONEE RIVER (R.M. 17.0-8.0)
   QUALITY DATA BASED ON EXISTING LAND USE

********************** INPUT DATA *********************

BEGINNING OF REACH RIVER MILE           17.00
END OF REACH        RIVER MILE           8.00
SUBREACH LENGTH (MILES)                   .50
COMPUTATION INTERVAL (HOURS)                2

FIRST DAY OF SIMULATION PERIOD            274   ( 1 OCT 70)
LAST DAY OF SIMULATION PERIOD             304   (31 OCT 70)
NUMBER OF DAYS IN SIMULATION PERIOD        31

OBSERVATIONS AT RIVER MILE              11.50
FIRST DAY OF STUDY PERIOD                 274   ( 1 OCT 70)
LAST DAY OF STUDY PERIOD                  304   (31 OCT 70)
NUMBER OF DAYS IN STUDY PERIOD             31
*******************************************************

WATER QUALITY PARAMETERS AT RIVER MILE        11.50
NUMBER OF SIMULATION POINTS                     373
```

PARAMETER	SIMULATION VALUES MINIMUM	MAXIMUM	MEAN	STD.DEV.	ERROR (SIMULATED-OBS.) MEAN	STD.DEV.	NO. OF OBSERVED VALUES
FLOW	8.9	37.1	12.7	5.9			
TEMP	9.2	24.9	17.7	3.4	0.0	0.0	0
OXY	8.0	11.2	9.5	.6	0.0	0.0	0
NH3	.080	.475	.391	.084	0.000	0.000	0
NO3	.220	1.219	1.063	.166	0.000	0.000	0
PO4	.100	.566	.440	.103	0.000	0.000	0
ALKA	25.0	31.2	30.0	.8	0.0	0.0	0
LOG COLI	2.78	4.44	3.03	.42	0.00	0.00	0
TDS	100.	103.	102.	1.	0.	0.	0
PH	7.3	7.7	7.6	.1	0.0	0.0	0
BOD	.5	4.1	2.9	.7	0.0	0.0	0

PARAMETER	WATER QUALITY STANDARD	POINTS EXCEEDING STANDARD NUMBER	PERCENT
TEMP	32.2 MAX.	0	0.00
OXY	4.0 MIN.	0	0.00
LOG COLI	3.60 MAX.	52	13.94
PH	6.0 MIN.	0	0.00
PH	8.5 MAX.	0	0.00

TABLE V-13
GEORGIA WATER QUALITY STANDARDS
AND
OCONEE RIVER STREAM CLASSIFICATION

DRINKING WATER STANDARDS
(waters requiring treatment)

Coliform	maximum	4000 MPN/100 ml
Dissolved Oxygen (warm water fish)	minimum	4 mg/l
pH	minimum	6.0
	maximum	8.5
Temperature	maximum	90°F
NO_3 as Nitrogen	maximum	10 mg/l

FISHING WATER STANDARDS

Coliform	maximum	4000 MPN/100 ml
Dissolved Oxygen (warm water fish)	minimum	4 mg/l
pH	minimum	6.0
	maximum	8.5
Temperature	maximum	90°F

STREAM CLASSIFICATION

North Oconee River	R.M. 34.8-23.7	Drinking Water
	R.M. 23.7-12.3	Fishing Water
Middle Oconee River	R.M. 31.5-21.8	Drinking Water
Middle & Main Oconee River	R.M. 21.8- 0.0	Fishing Water

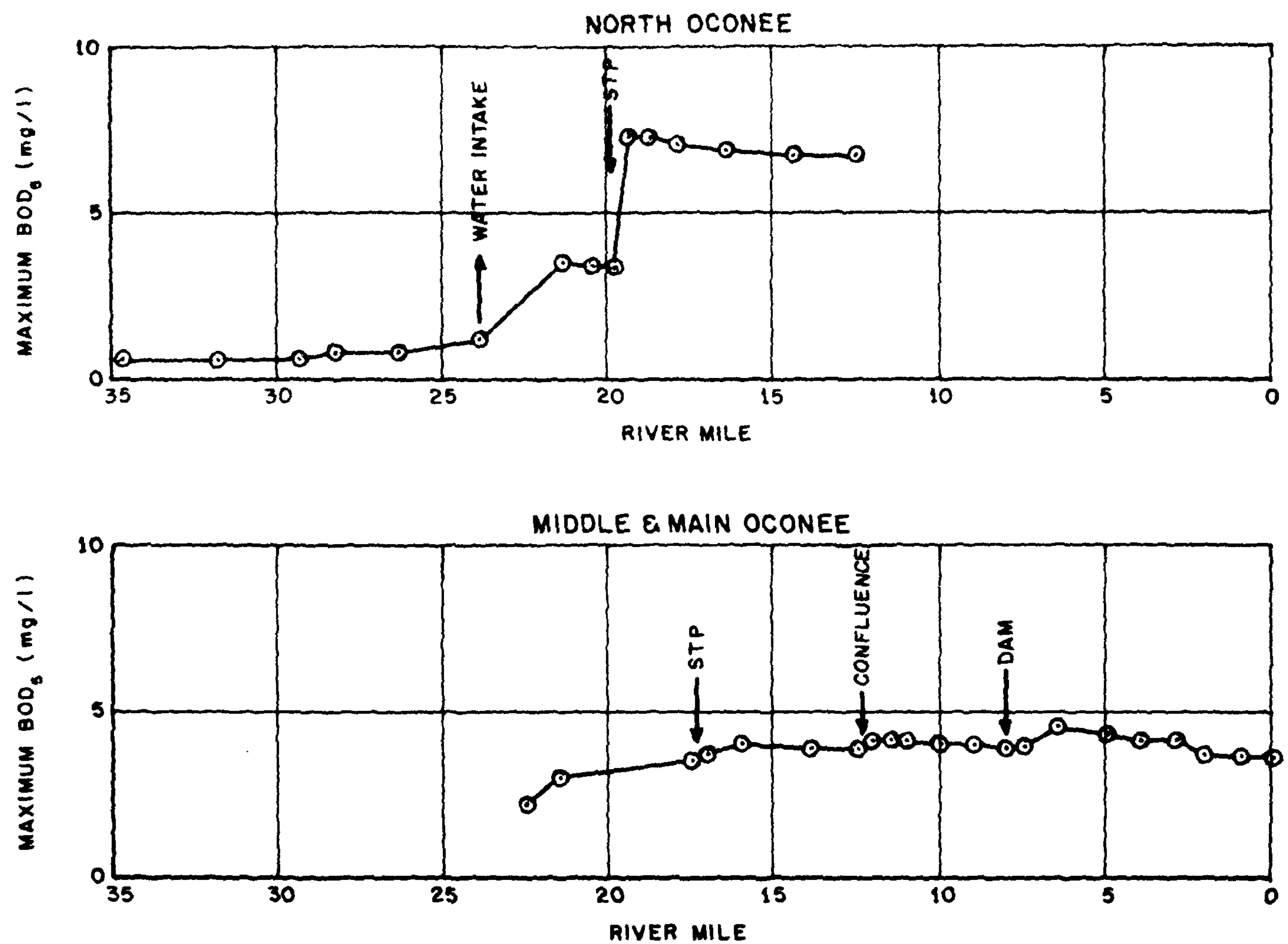

Figure V-1. Existing Land Use

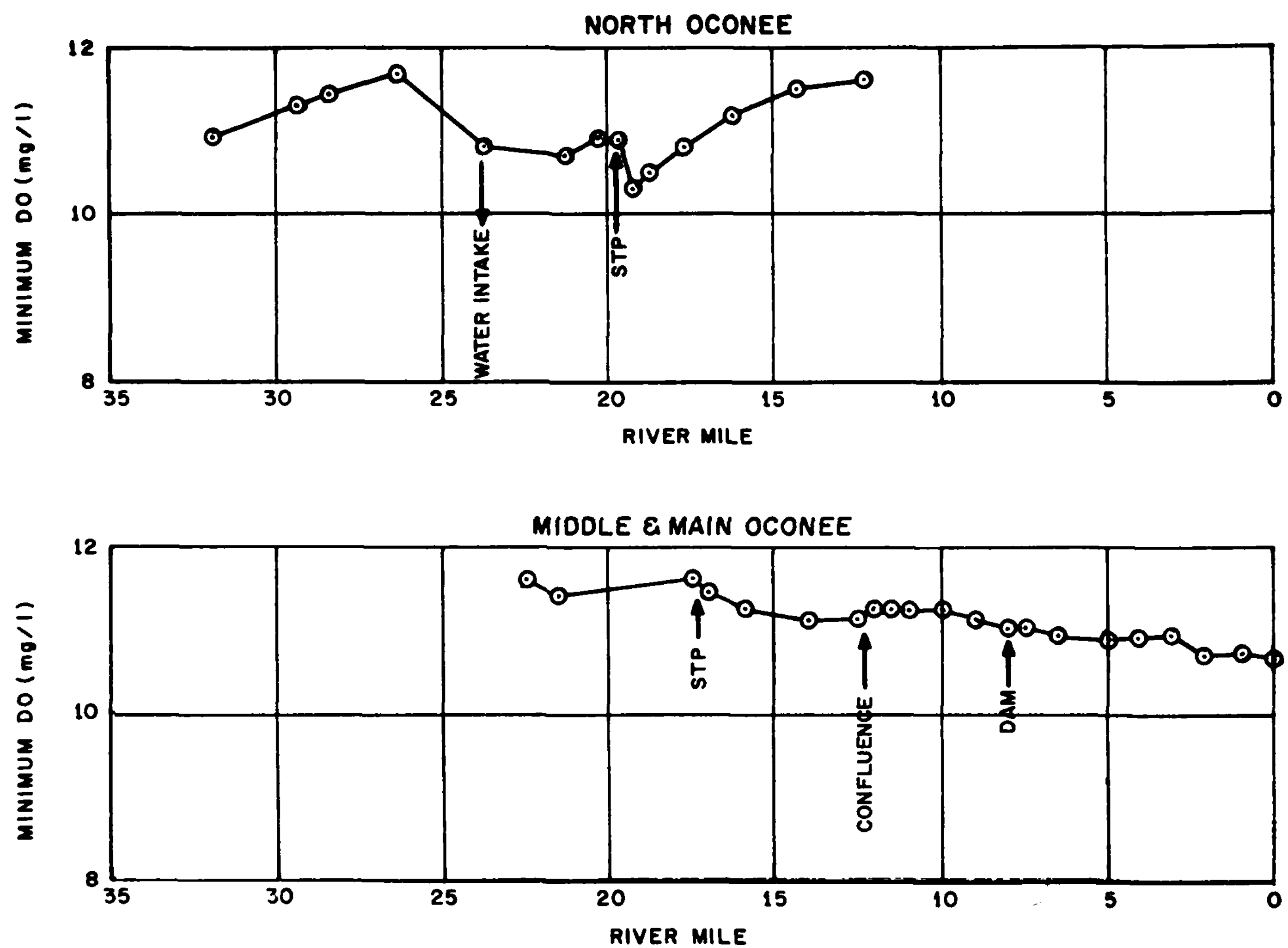

Figure V-2. Existing Land Use

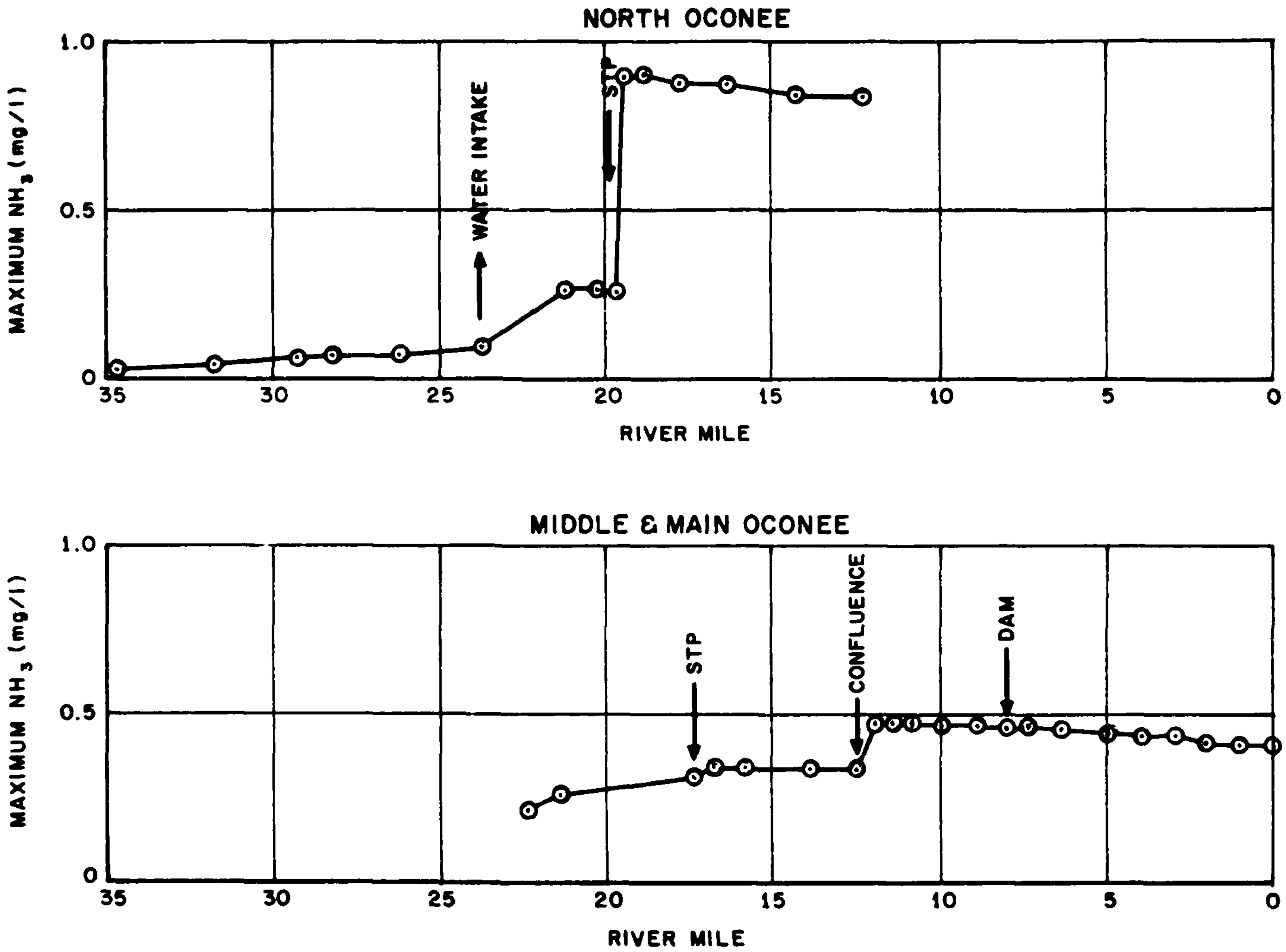

Figure V-3. Existing Land Use

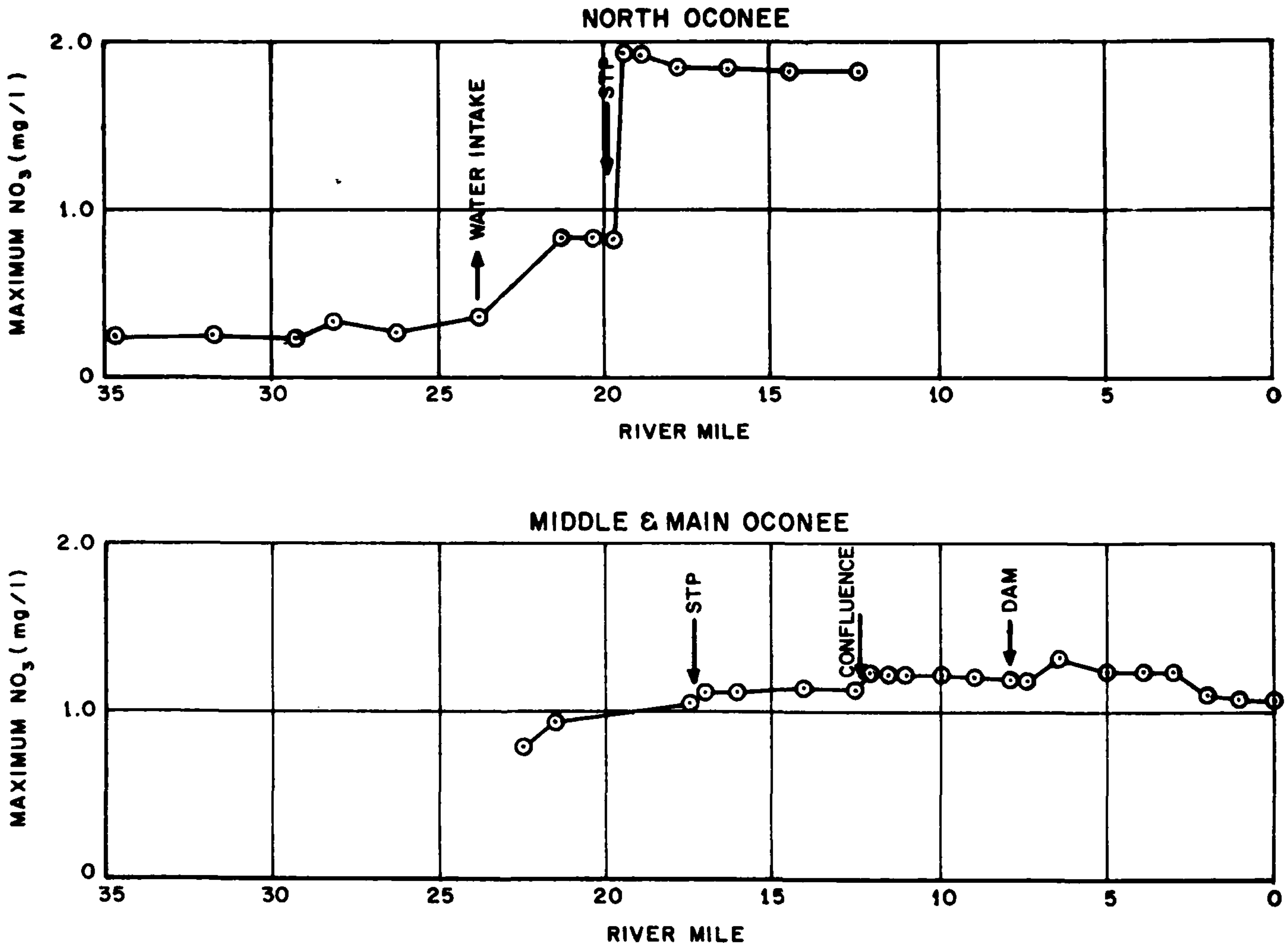

Figure V-4. Existing Land Use

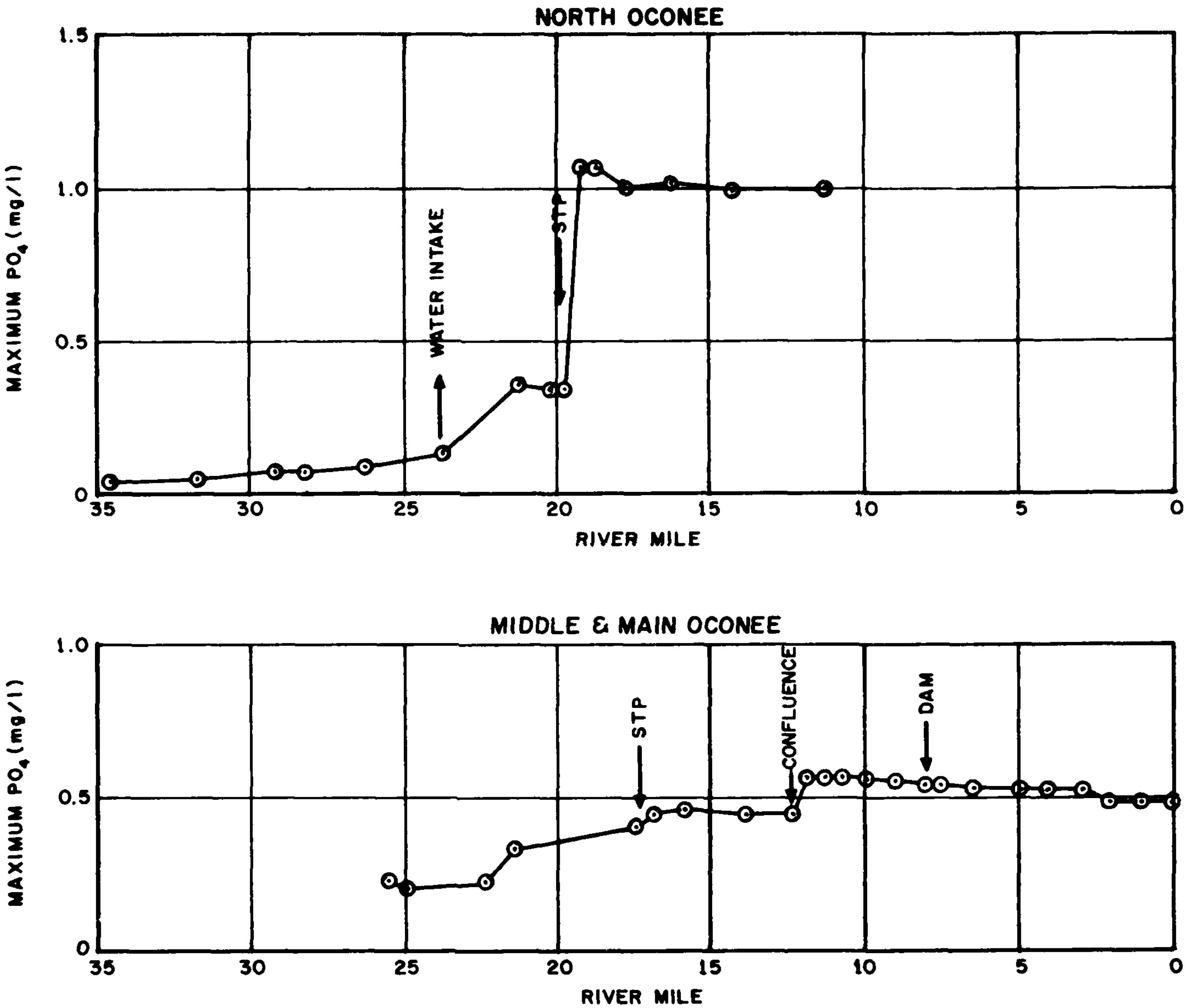

Figure V-5. Existing Land Use

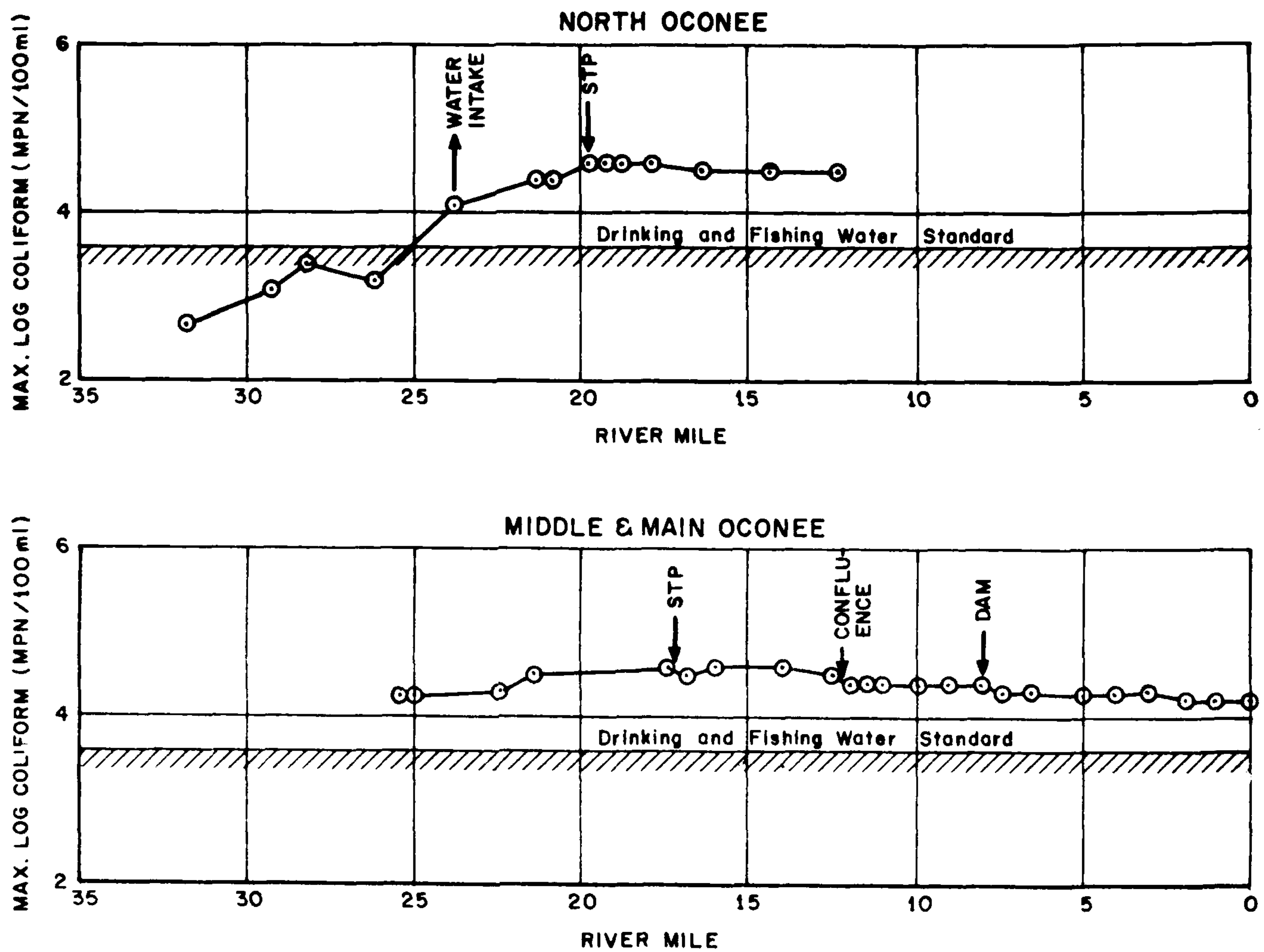

Figure V-6. Existing Land Use

TABLE V-14
POINT SOURCE IMPACTS ON THE NORTH OCONEE RIVER
EXISTING LAND USE

RIVER MILE	PROBABLE POLLUTANT SOURCE	PARAMETER	IMPACT	REMARKS
26.0-23.7	Unknown	DO	.8 mg/l	minor
	Subbasin 1A & 2	Coliform	9000 MPN/100 ml	significant
23.2-21.7	Subbasin 3	BOD_5	2.5 mg/l	minor
		NH_3	.2 mg/l	significant
		NO_3	.5	significant
		PO_4	.2 mg/l	significant
19.9-19.3	STP	DO	.6 mg/l	minor
		BOD_5	4 mg/l	minor
		NH_3	.6 mg/l	significant
		NO_3	1.1 mg/l	significant
		PO_4	.7 mg/l	significant

TABLE V-15
POINT SOURCE IMPACTS ON THE MIDDLE AND MAIN OCONEE RIVER
EXISTING LAND USE

RIVER MILE	PROBABLE POLLUTANT SOURCE	PARAMETER	IMPACT	REMARKS
22.5-17.0	STP & Subbasin 6A & 6B	NH_3	.1 mg/l	significant
		NO_3	.2 mg/l	significant
		PO_4	.1 mg/l	significant
		BOD_5	1.5 mg/l	minor
12.3	North Oconee	NH_3	.1 mg/l	significant
		PO_4	.1 mg/l	significant
7.2	Subbasin 16	BOD_5	.5 mg/l	minor
		NH_3	.1 mg/l	significant

Analysis of Alternative Future C

The STORM results derived from alternative future C land use condition were imposed on the same initial river quality condition as defined for existing land use in Table V-10. The tributary base flow quality condition used for alternative C land use is shown in Table V-16. Table V-17 shows an example of a statistical summary of the water quality condition at a random point along the river for alternative future C land use condition. The critical values for some of these parameters at various locations along the river have been plotted in Figures V-7 to V-12 to show a river water quality profile for the most critical condition occurring during the period simulated for dissolved oxygen (DO), ammonia (NH_3), nitrate (NO_3), phosphate (PO_4), log coliform bacteria and 5-day carbonaceous biochemical oxygen demand (BOD_5).

The water quality condition for alternative future C land use condition exceeds the Georgia State Water Quality Standards (i.e., Table V-13) similar to the existing condition.

Sample graphical results of the simulations are shown in Appendix B.

TABLE V-16
TRIBUTARY BASE FLOW QUALITY DATA 1/
ALTERNATIVF C LAND USE

	Sub-Basin	River Mile	Drainage Area(mi^2)	Population	Base Flow (cfs)	DO (mg/l)	BOD5 (mg/l)	Coliform (MPN/100ml)	Detritus (mg/l)	NH_3 (mg/l)	NO_3 (mg/l)	NO_2 (mg/l)	PO_4 (mg/l)	TDS (mg/l)	pH	Alkalinity (mg/l)
REACH	NO. 1															
Upper	Limit	34.8	----	--	2/	8.0	.5	430	5	.03	.24	.01	.03	100	7.1	36
	20	34.8	2.9	32	1.4	8.0	.5	660	5	.08	.22	.01	.1	100	7.1	36
	17	33.5	5.8	128	2.9	8.0	.5	660	5	.08	.22	.01	.1	100	7.1	36
	18	31.8	8.8	152	4.3	8.0	.5	660	5	.08	.22	.01	.1	100	7.1	36
	19	31.0	3.4	358	1.7	8.0	.5	660	5	.08	.22	.01	.1	100	7.1	36
	1B	28.7	5.8	1921	2.9	8.0	.5	660	5	.08	.22	.01	.1	100	7.1	36
	1A	26.0	4.6	3573	2.3	8.0	.5	660	5	.08	.22	.01	.1	100	7.1	36
	2	24.3	64.5	9788	31.9	8.0	.5	660	5	.08	.22	.01	.1	100	7.1	36
REACH	NO. 2															
(DWF)	3	23.2	3.6	7673	13.1	8.0	3.1	1330	5	.23	.67	.01	.2	100	7.1	36
(DWF)	4	21.7	12.4	14174	34.4	8.0	2.4	980	5	.18	.62	.01	.2	100	7.1	36
(DWF)	12B	20.3	2.7	3996	5.1	8.0	3.9	1690	5	.30	.90	.01	.3	100	7.1	36
	STP	19.9	---	----	15.3	0.0	99.0	200	8.25	10.0	20.0	.05	12.0	244	6.7	100
(DWF)	12C	19.0	3.6	6020	14.0	8.0	2.4	1010	5	.18	.62	.01	.2	100	7.1	36
	12A	15.6	5.0	3827	2.5	8.0	.5	660	5	.08	.22	.01	.1	100	7.1	36
REACH	NO. 3															
Upper	Limit	31.5	----	----	3/	8.0	.5	930	5	.10	.60	.01	.06	100	7.5	25
	5C	31.2	5.4	293	2.7	8.0	.5	660	5	.08	.22	.01	.1	100	7.5	25
	5D	29.5	20.3	1416	10.1	8.0	.5	660	5	.08	.22	.01	.1	100	7.5	25
(DWF)	5A	25.9	8.9	12985	10.2	8.0	6.3	2720	5	.48	1.42	.01	.5	100	7.5	25
	5B	24.6	5.3	2216	2.6	8.0	.5	660	5	.08	.22	.01	.1	100	7.5	25
(DWF)	6B	22.0	4.2	10727	12.7	8.0	4.2	1820	5	.33	.97	.01	.3	100	7.5	25
(DWF)	6A	19.9	5.4	12656	14.1	8.0	4.4	1930	5	.35	1.05	.01	.3	100	7.5	25
	STP	17.3	---	-----	5.0	0.0	84	200	7.25	10.0	20.0	.05	12.0	154	7.3	100
	7	17.1	42.8	5536	21.2	8.0	.5	660	5	.08	.22	.01	.1	100	7.5	25

TABLE V-16 (Cont'd)
TRIBUTARY BASE FLOW QUALITY DATA[1/]
ALTERNATIVE C LAND USE

	Sub-Basin	River Mile	Drainage Area (mi^2)	Population	Base Flow (cfs)	DO (mg/l)	BOD5 (mg/l)	Coliform (MPN/100ml)	Detritus (mg/l)	NH_3 (mg/l)	NO_3 (mg/l)	NO_2 (mg/l)	PO_4 (mg/l)	TDS (mg/l)	pH	Alkalinity (mg/l)
REACH	NO. 4															
(DWF)	8	17.0	16.0	12462	15.6	8.0	3.9	1720	5	.30	.90	.01	.3	100	7.5	25
	9	16.5	2.0	1724	1.0	8.0	.5	660	5	.08	.22	.01	.1	100	7.5	25
	10	15.1	9.3	4104	4.6	8.0	.5	660	5	.08	.22	.01	.1	100	7.5	25
	11	12.9	5.4	231	2.7	8.0	.5	660	5	.08	.22	.01	.1	100	7.5	25
(DWF)	13	11.4	5.4	8619	6.2	8.0	6.9	2990	5	.53	1.57	.01	.5	100	7.5	25
	15	9.8	4.8	1753	2.4	8.0	.5	660	5	.08	.22	.01	.1	100	7.5	25
	14	8.9	7.8	1192	3.9	8.0	.5	660	5	.08	.22	.01	.1	100	7.5	25
REACH	NO. 5															
	16	7.2	17.6	6282	8.7	8.0	.5	660	5	.08	.22	.01	.1	100	7.5	25
	21	5.8	10.8	42	5.4	8.0	.5	660	5	.08	.22	.01	.1	100	7.5	25
	23	2.8	4.0	0	2.0	8.0	.5	660	5	.08	.22	.01	.1	100	7.5	25
	22	2.8	61.8	1084	30.6	8.0	.5	660	5	.08	.22	.01	.1	100	7.5	25
	25	0.8	15.4	0	7.6	8.0	.5	660	5	.08	.22	.01	.1	100	7.5	25
	24	0.0	2.1	0	1.0	8.0	.5	660	5	.08	.22	.01	.1	100	7.5	25

1/ Water temperature during storms equals the hourly air temperature, but during non-storm events water temperature equals the mean daily air temperature minus 2°C.

2/ Inflow at upper limit on the North Oconee River is taken as 43% of gaged flow on Middle Oconee River at USGS gage 2-2175.

3/ Inflow at upper limit on the Middle Oconee River is taken as 90% of gaged flow on Middle Oconee River at USGS gage 2-2175.

TABLE V-17
WATER QUALITY AT RIVER MILE 11.5
ALTERNATIVE FUTURE C LAND USE

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****************************************
 POST-PROCESSOR FOR WQRRS     APRIL 1976
HYDROLOGIC ENGINEERING CENTER  DAVIS, CA
****************************************

   OCONEE RIVER WATER QUALITY STUDY    **WQRRS STATISTICAL POST-PROCESSOR**
   REACH 4  MIDDLE OCONEE RIVER (R.M. 17.0-8.0)
   QUALITY DATA BASED ON ALTERNATIVE C LAND USE

*********************** INPUT DATA **********************

BEGINNING OF REACH RIVER MILE          17.00
END OF REACH       RIVER MILE           8.00
SUBREACH LENGTH (MILES)                  .50
COMPUTATION INTERVAL (HOURS)               2

FIRST DAY OF SIMULATION PERIOD           274   ( 1 OCT 70)
LAST DAY OF SIMULATION PERIOD            304   (31 OCT 70)
NUMBER OF DAYS IN SIMULATION PERIOD       31

OBSERVATIONS AT RIVER MILE             11.50
FIRST DAY OF STUDY PERIOD                274   ( 1 OCT 70)
LAST DAY OF STUDY PERIOD                 304   (31 OCT 70)
NUMBER OF DAYS IN STUDY PERIOD            31
*******************************************************

WATER QUALITY PARAMETERS AT RIVER MILE     11.50
NUMBER OF SIMULATION POINTS                  373
```

PARAMETER	SIMULATION VALUES MINIMUM	MAXIMUM	MEAN	STD.DEV.	ERROR (SIMULATED-OBS.) MEAN	STD.DEV.	NO. OF OBSERVED VALUES
FLOW	9.7	37.9	13.9	6.2			
TEMP	9.2	24.8	17.6	3.4	0.0	0.0	0
OXY	8.0	11.2	9.5	.6	0.0	0.0	0
NH3	.080	.625	.518	.115	0.000	0.000	0
NO3	.220	1.531	1.328	.230	0.000	0.000	0
PO4	.100	.740	.590	.139	0.000	0.000	0
ALKA	25.0	32.3	30.8	1.0	0.0	0.0	0
LOG COLI	2.82	4.53	3.10	.46	0.00	0.00	0
TDS	100.	105.	104.	1.	0.	0.	0
PH	7.3	7.6	7.5	.1	0.0	0.0	0
BOD	.5	5.1	3.9	.9	0.0	0.0	0

```
**********************************************************************
```

PARAMETER	WATER QUALITY STANDARD	POINTS EXCEEDING STANDARD NUMBER	PERCENT
TEMP	32.2 MAX.	0	0.00
OXY	4.0 MIN.	0	0.00
LOG COLI	3.60 MAX.	58	15.55
PH	6.0 MIN.	0	0.00
PH	8.5 MAX.	0	0.00

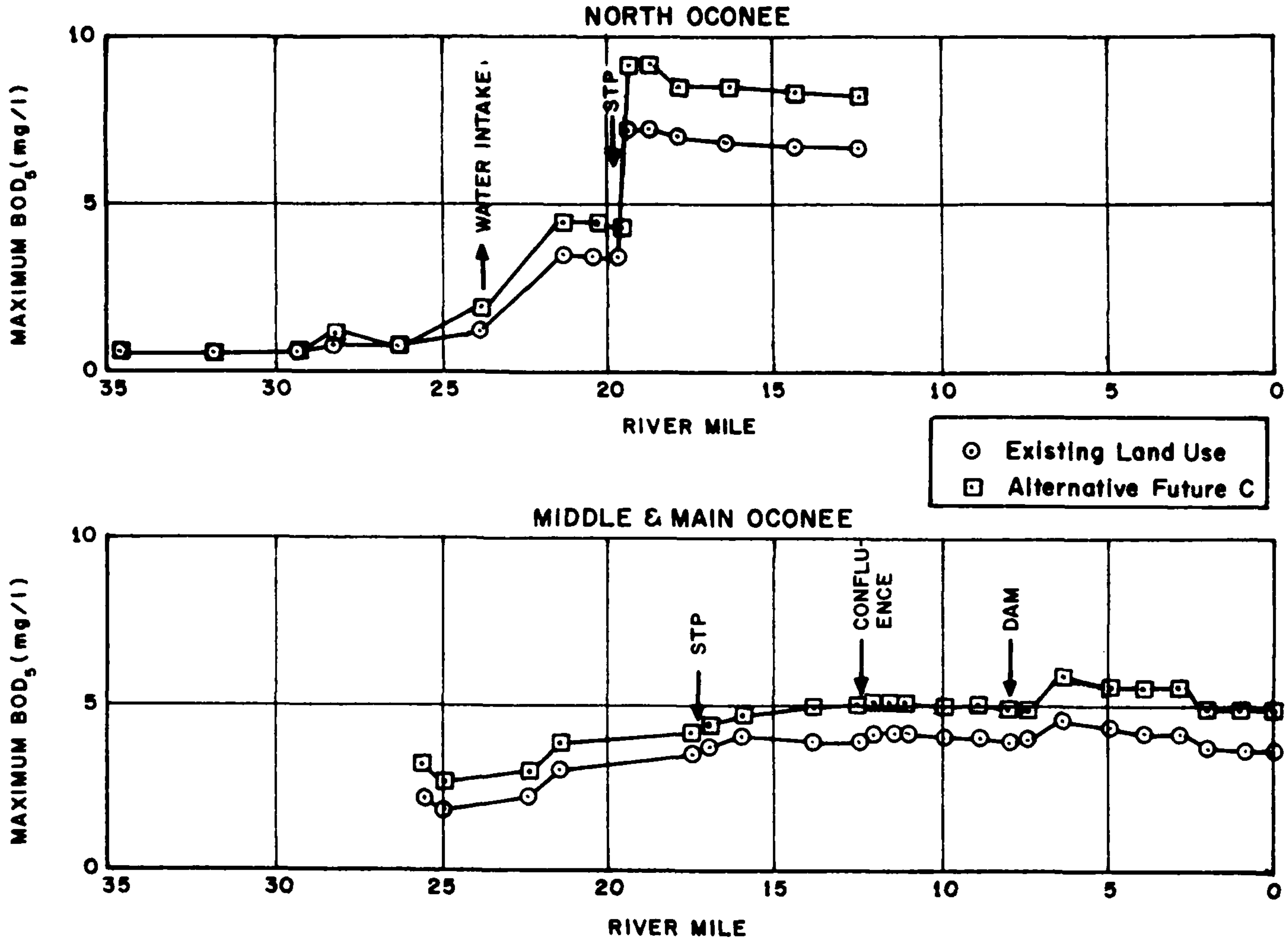

Figure V-7. Comparison of Water Quality Due to Changing Land Use

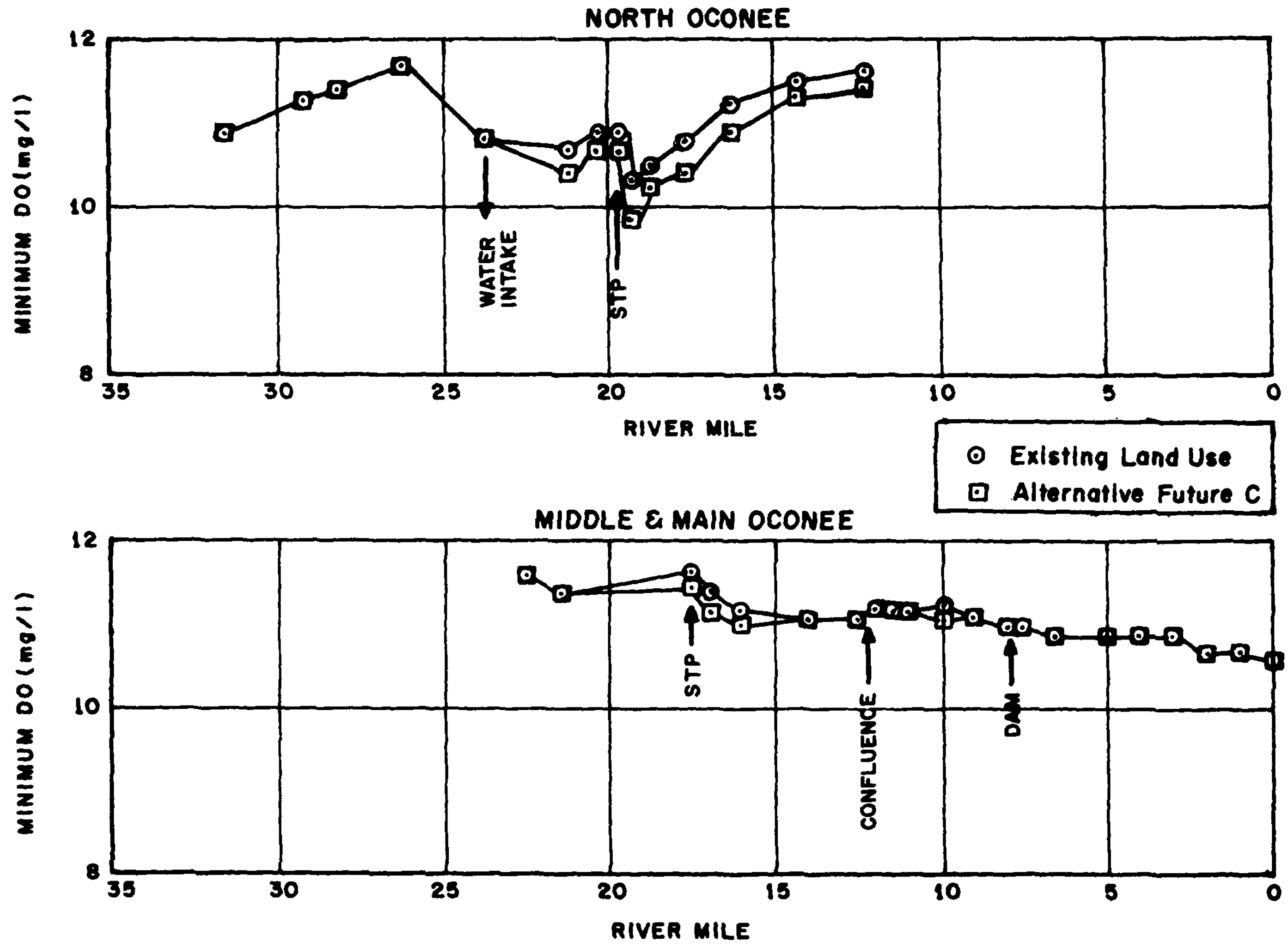

Figure V-8. Comparison of Water Quality Due to Changing Land Use

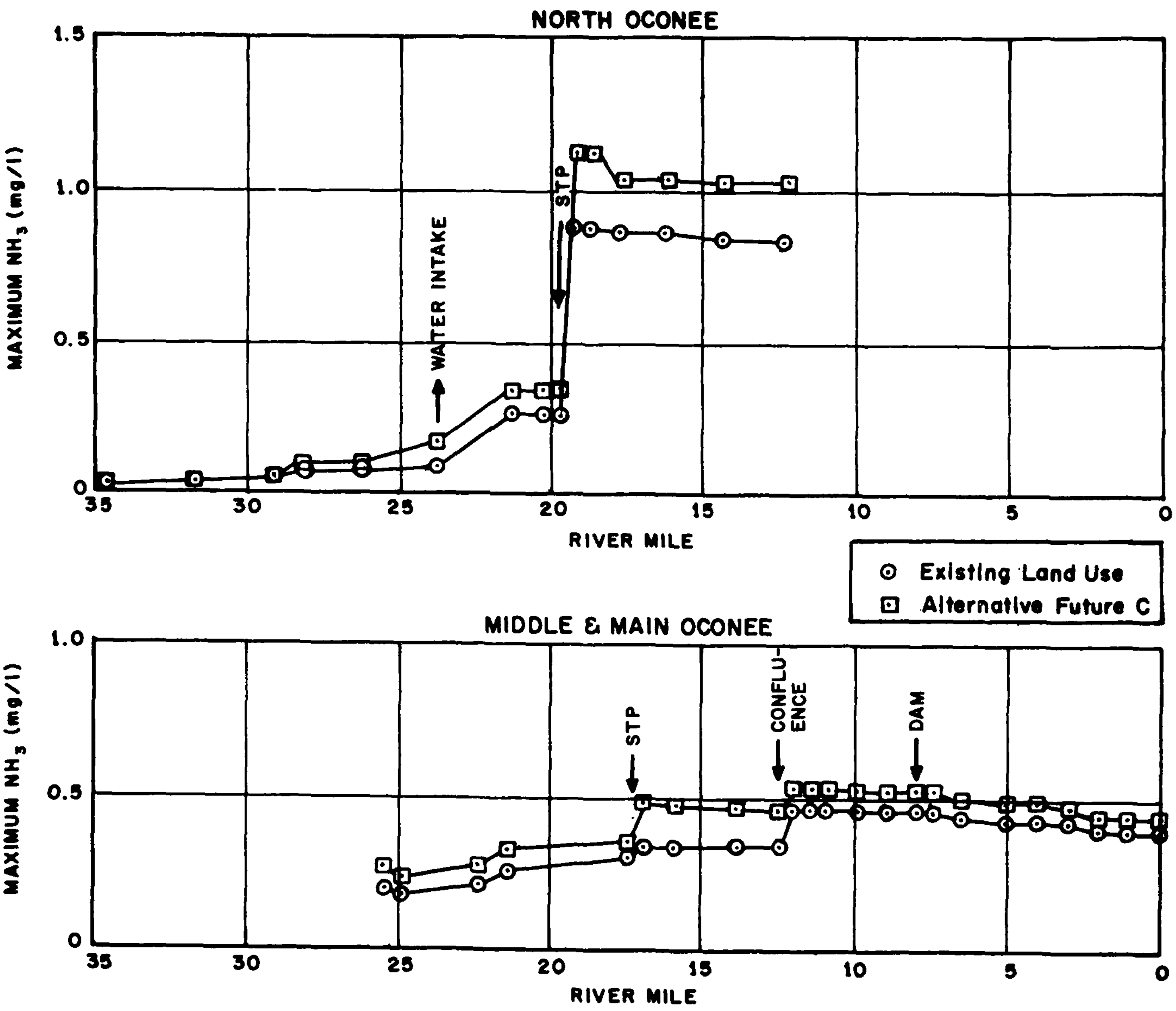

Figure V-9. Comparison of Water Quality Due to Changing Land Use

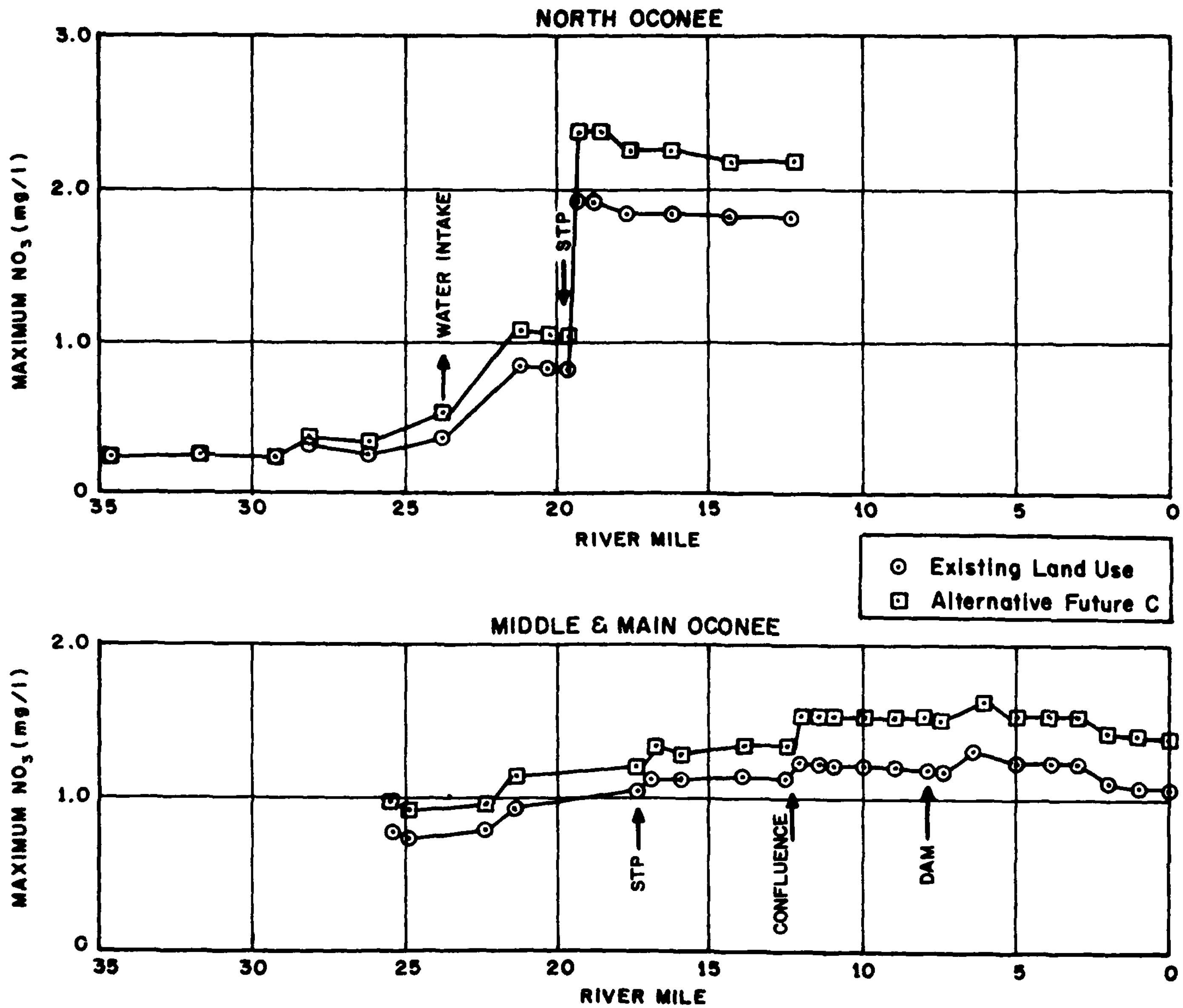

Figure V-10. Comparison of Water Quality Due to Changing Land Use

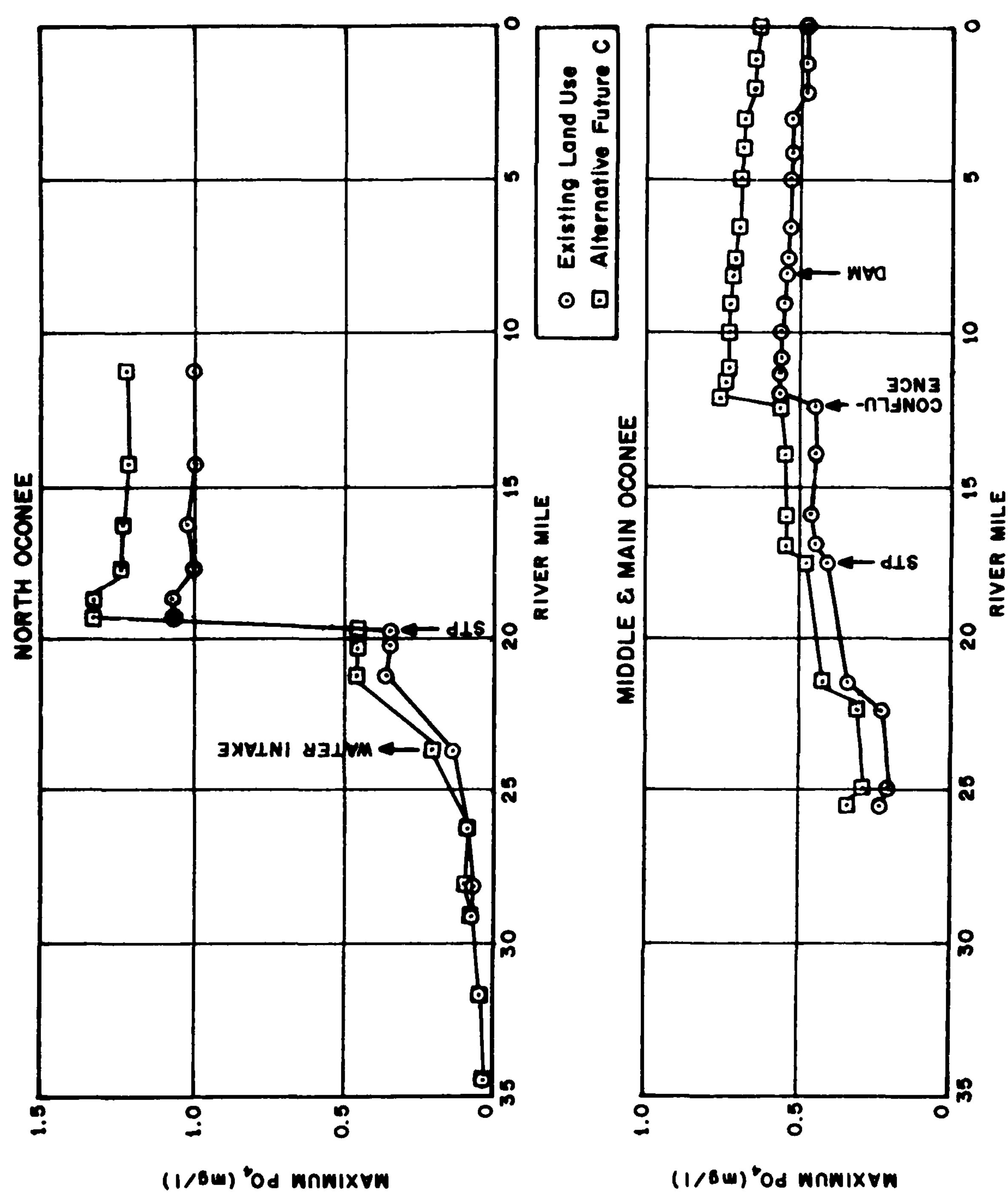

Figure V-11. Comparison of Water Quality Due to Changing Land Use

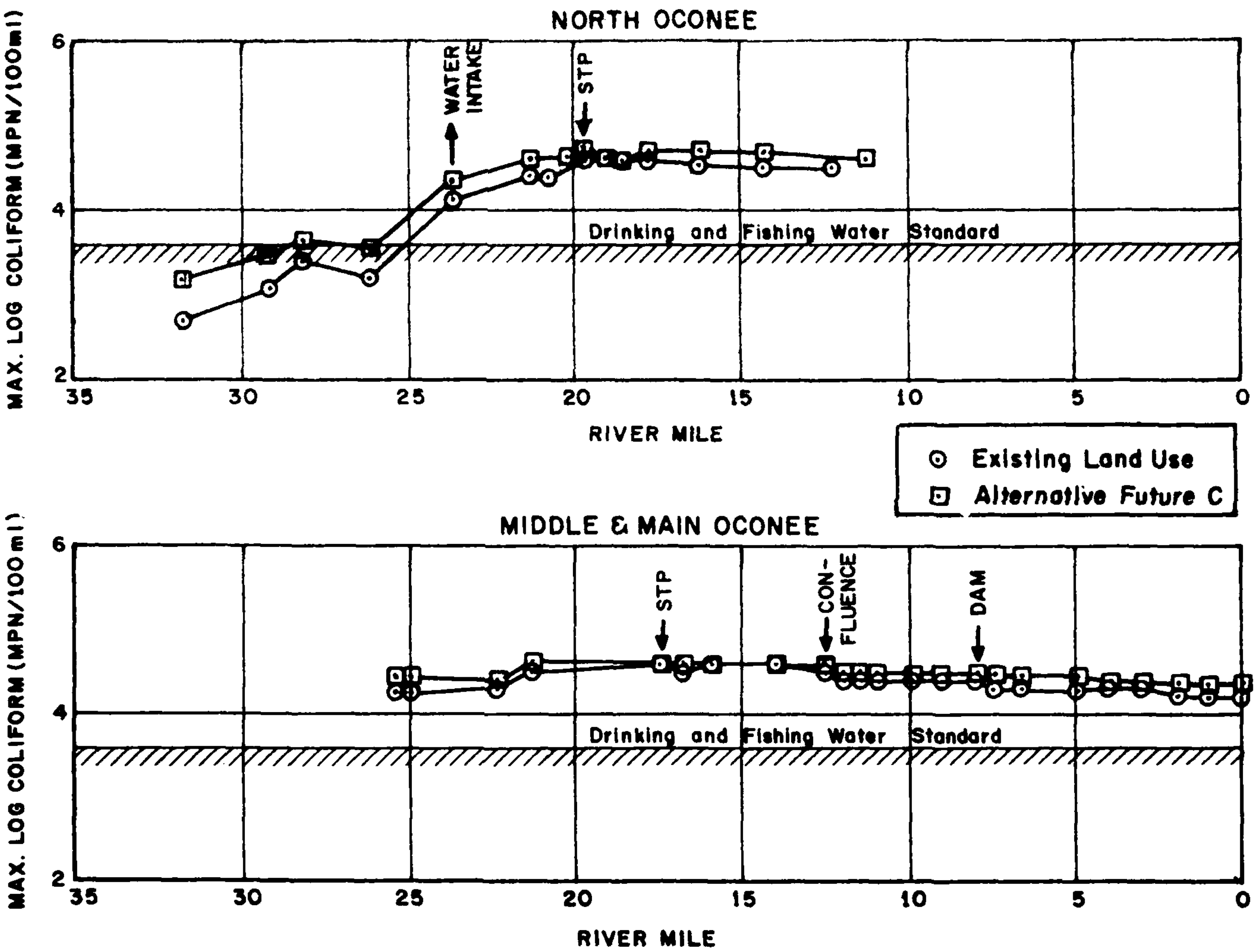

Figure V-12. Comparison of Water Quality Due to Changing Land Use

Impact of Alternative Future C

The water quality impact of alternative future C land use is shown in Figures V-7 to V-12. They have been summarized in Table V-18.

TABLE V-18
WATER QUALITY IMPACTS DUE TO CHANGING FROM EXISTING LAND USE TO ALTERNATIVE FUTURE C

PARAMETER	MAGNITUDE (mg/l)	LOCATION (river mile)		SIGNIFICANCE
BOD_5	1-2	North Oconee	25-12.3	minor
	1	Middle Oconee	25-0	minor
DO	.2-.4	North Oconee	22-12.3	minor
	.2	Middle Oconee	18-15	minor
NH_3	.1-.2	North Oconee	25-12.3	significant
	.1-.2	Middle Oconee	25-0	significant
NO_3	.1-.4	North Oconee	25-12.3	significant
	.1-.3	Middle Oconee	25-0	significant
PO_4	.1-.3	North Oconee	25-12.3	significant
	.1-.2	Middle Oconee	25-0	significant
Coliform (MPN/100ml)	3,000-10,000	North Oconee	33-12.3	significant
	3,000-10,000	Middle Oconee	25-0	significant

Remarks in Table V-18 concerning nutrients having significant impacts refer to the potential impact on algal production in non-turbid water. Unless significant improvement occurs in the turbidity of the Oconee River, this potential will not be realized.

In general, the sources of the increased pollutants due to changing land use are the same as those defined for existing conditions in Tables V-14 and V-15. Concentrations of pesticides, heavy metals and other parameters not specifically mentioned were not evaluated in this study.

GRID CELL SEDIMENT TRANSPORT INVESTIGATIONS

Introduction

A distributed parameter, structure imitating model was developed for the calculation of land surface erosion and deposition. The phenomena simulated in the model are: rainfall-runoff, runoff accumulation and distribution, detachment of soil by rainfall, transport of detached soil by runoff, scour by runoff, and deposition. Application of the model to laboratory test data yielded encouraging results. The application to a watershed in this study was unsuccessful, however, because of unsatisfactory topographical information.

Model Description

The model performs calculations on a cell-by-cell basis. The direction and velocity of runoff are determined from topographical information imbedded in the data base. A steady state process is assumed. Details of the computations are given below.

Rainfall-Runoff

The very simple "rational formula" was used to generate runoff from each cell. The runoff from any cell is:

$$Q = ciA$$

where:

Q = discharge, cfs

c = runoff coefficient

i = rainfall intensity, in/hr

A = cell area, acres

TABLE V-19

MANNING N = .05000 RELAXATION FACTOR, F = .50

RAIN (IN/HR) DURATION (HR)

1.00 1.00

RUNOFF COEFFICIENTS

LAND USE	HYDROLOGIC SOIL TYPE 1	2	3	4	EXPOSURE
1	.10	.15	.20	.25	.10
2	.30	.37	.43	.50	.40
3	.25	.30	.35	.40	.30
4	.50	.57	.63	.70	.25
5	.10	.17	.23	.30	.90
6	.55	.65	.75	.85	.05
7	.50	.57	.63	.70	.20
8	.10	.17	.23	.30	.95
9	.70	.76	.87	.95	.05
10	.50	.57	.63	.70	.20
11	.80	.55	.90	.95	.15
12	.10	.17	.23	.30	.80
13	1.00	1.00	1.00	1.00	0.00

The value of the coefficient, c, was determined from a combination of hydrologic soil type and land use as shown in Table V-19. The values in the table are judgemental and have not been calibrated.

It is believed that use of this rainfall-runoff relationship is justified because of the small scale of the cells and the steady state nature of the simulation. The method for accumulating runoff from individual cells is described below.

Runoff Accumulation

Consider a typical cell (I, J) and its eight neighboring cells as shown in Fig. V-13. If any of the neighboring cells are at higher elevations, a portion of runoff generated at those cells will reach cell (I, J). The runoff generated within cell (I, J) is found by the rational formula and added to the sum of all the contributions from higher cells to give the total discharge passing out of cell (I, J). This discharge is evenly distributed among all neighboring cells of lower elevation. For this reason computations must proceed from higher elevations to lower which requires that the data bank first be sorted by elevation. Note that, since the sediment moves with the runoff, this portion of the calculations also determines the paths that the sediment takes. No runoff (or sediment) is passed between cells of equal elevation.

Soil Detachment by Rainfall

Following a suggestion by Foster and Meyer [14] it is assumed that rate of detachment is proportional to the square of the rainfall intensity with

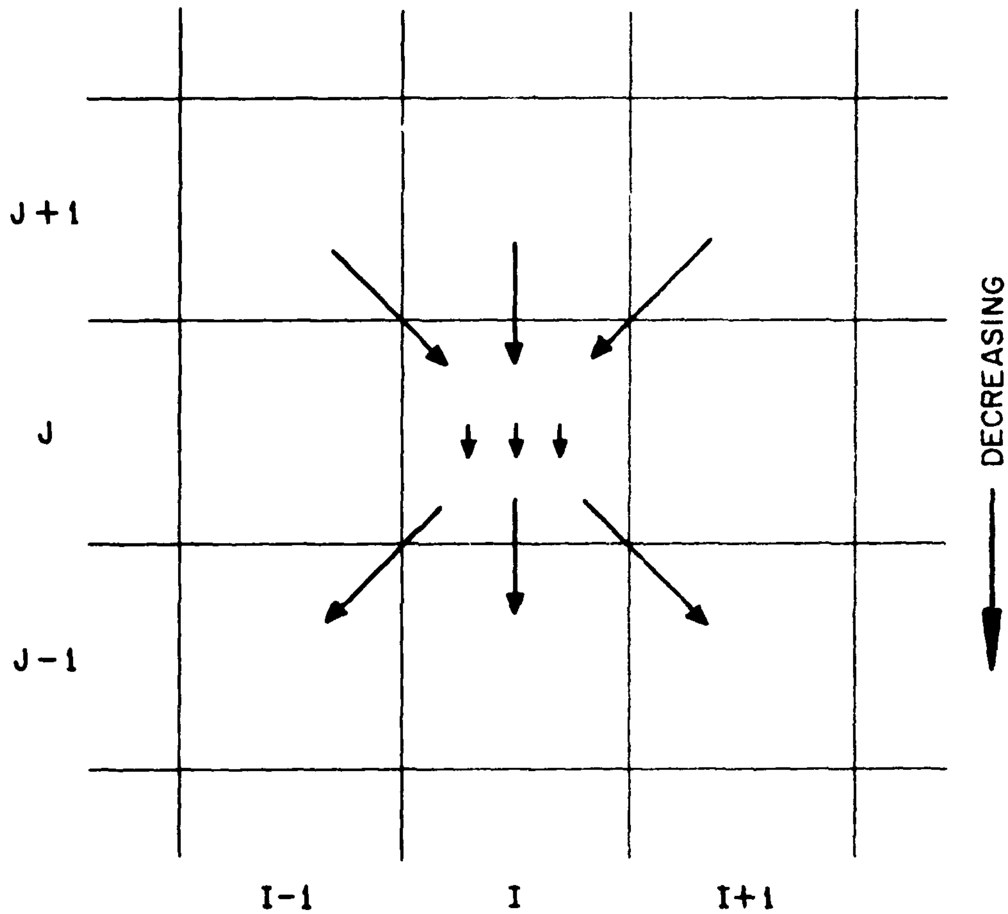

Figure V-13. Definition Sketch for Grid-Cell Computations.

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OCONEE RIVER WATER QUALITY AND SEDIMENT ANALYSIS.(U)
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the proportionality constant being the erodibility factor (K) in the universal soils loss equation. The formula used is:

$$RE = a\,(K)(Ex)(A)(i^2)$$

where:

RE = rate of soil detachment by rainfall, tons/hr

a = an empirical constant, the value used (0.0002) was based on very sparse data

K = soil erodibility factor in the universal soils loss equation, related to soil type

Ex = percent of the cell area exposed to rainfall, related to land use as shown on Table V-19

A = cell area, ft^2

i = rainfall intensity, in/hr

In this study, the rainfall is assumed to be uniformly distributed over the basin and all cells are assumed to be of equal size. Therefore, only the values of K and Ex change from cell to cell to reflect spatial land use variation.

Sediment Transport by Runoff

The hydraulics of the flow must be further defined before sediment transport calculations can begin. To define the hydraulics certain important assumptions must be made. The formation of rills and gullies is important to the runoff hydraulics, however no means of predicting their formation or ultimate size was found. Therefore, it was assumed the runoff between cells occurs as sheet flow. The width scale, B, of the runoff is, therefore, related to the total length of a cell boundary and the number of neighboring cells to which runoff is passed (those with lower elevations). If flow goes to all eight neighbors, B equals the total length of the cell coundary; if flow goes to only one cell, B is one-eighth of the total, etc. From the width, B, a typical depth of flow, y for each outflow path is calculated from the Manning eq.:

$$y = \left[\frac{Qn}{1.486\ B\ S^{1/2}}\right]^{0.6}$$

where:

y = depth of flow, ft.

Q = total discharge from cell, cfs

n = Manning's n

B = width of outflow path, ft.

S = slope to particular cell, difference in elevation divided by distance between cell centroids

Sediment transport rates and erosion or deposition by the runoff are based on a simple DuBoys relationship:

$TC = CS(\tau - \tau m)\ b$

where:

TC = transport capacity of any single outflow path, tons/hr

CS = transport coefficient, related to representative grain size: $CS = 52.3\ D^{-0.75}$, where D is grain size in millimeters, empirically related to soil type

τ = shear stress, lb/ft^2

$\tau = \gamma yS$, where γ = unit weight of water and y and S are as previously defined

τm = critical shear stress below which no transport occurs, lb/ft^2 related to grain size

b = width of an individual outflow path. Constant at one-eighth the total length of a cell boundary

Whether scour or deposition occurs along any particular outflow path depends upon whether the sediment load is less than or greater than the transport capacity. The load to any outflow path is calculated as follows:

g = (GI + RE) (QØPS/QØ)

where:

g = sediment inflow to any particular outflow path, tons/hr

GI = total rate of sediment inflow to the cell from neighboring cells of higher elevation, tons/hr

RE = rate of sediment detachment by raindrop within the cell, ton/hr.

QØPS = runoff following individual outflow path, cfs, equal to QØ divided by the number of outflow paths

QØ = total runoff from cell, cfs

If g is less than the transport capacity, erosion occurs along the outflow path. The actual transport rate for that path is calculated by the following:

G2N = g (1 - Ex) + ((1 - F) g + F(TC)Ex)

where:

G2N = sediment transported out of cell along any given outflow path, tons/hr

F = a relaxation factor if F = 0, outflow = inflow; if F = 1, outflow = transport capacity

Other symbols are as previously defined. The exposure factor appears because erosion can only occur where the soil is available.

If g is greater than the transport capacity, deposition occurs and the outflowing load is calculated as follows:

$$G2N = (1 - F)\, g + F\,(TC)$$

All symbols have been defined. The exposure does not appear because deposition can occur everywhere.

These values are added to the inflowing load (G1) of the neighboring cells.

Application to Laboratory Data

The algorithm for calculation of land surface erosion and deposition described above was tested by comparing calculated erosion rates with those measured in a laboratory. While such a test does not constitute rigorous verification, it can be used to evaluate the general validity of the approach and identify some inadequacies.

The laboratory test data used [15] is from a 5 foot by 16 foot plot. It was modeled using 25 - 1 by 1.6 feet rectangular cells. The roughness value (n = 0.022) and runoff coefficient (C = 0.97) were based on measurements made during the experiment. Although several slopes were tested, only the 10% slope condition was modeled. This slope was reflected in elevations assigned to the individual cells. The simulated rainfall intensities were used in the program and the calculated weight of sediment transported to the bottom of the plot compared with that measured. The results are shown in Table V-20.

The same set of coefficients was used for all rainfall intensities indicating that the functional relationship between rainfall and erosion used is reasonable. A relaxation coefficient, F, of zero had to be used. A zero F indicates that the runoff has sufficient transport capacity to carry all the sediment produced by raindrop erosion. Apparently the transport capacity calculated by the DuBoys relation was too small. This could be due to the assumed runoff hydraulics being inadequate, or the critical shear stress not being appropriate for land surface erosion. The critical shear stress was taken from a Shield's diagram [16] developed for open channel flow.

TABLE V-20

Rainfall Intensity (in/hr)	Measured Wt. of Sediment (lbs/hr)	Calculated Wt. of Sediment (lbs/hr)
1.25	5.3	7.6
2.25	27.1	24
3.65	67	66
4.60	106	106

Application to Sandy Creek Basin

The model was applied to the lower 16 square miles of the Sandy Creek watershed. An existing detailed data bank was available for this area. The spatial variation of various parameters within the watershed was described using a total of 9208 grid cells. The variables used from the data bank were: cell elevation, soil type, hydrologic soil type and land use. A topographic map of the basin is shown in Figure V-14.

Runoff coefficients were determined from land use and hydrologic soil type as given in Table V-19. Also shown are the exposure values assigned to the various land uses. Descriptions of the land uses are given in Chapter III, and soil erodibility factors (K) in Table V-5. After several runs and mapping of computed discharges and sediment loads, a basic data problem was identified which prevented completion of the application. This problem is discussed in detail below.

Topographic Data Problems

The procedure used relies on topographic data in the form of an elevation for each cell. Differential elevations between neighboring cells drive the runoff calculation. If the cell elevations are truly representative of the topography of a drainage basin, every cell but one will have at least one outflow path. The exception is the outlet on the watershed boundary.

The cell elevations in the Oconee study were manually assigned from a base topographic map. This procedure resulted in many cells for which no outflow path existed. Out of 9208 total cells, 334 had no outflow path. Since no runoff or sediment can pass through a cell with no outflow path, the calculations for all downhill cells are erroneous.

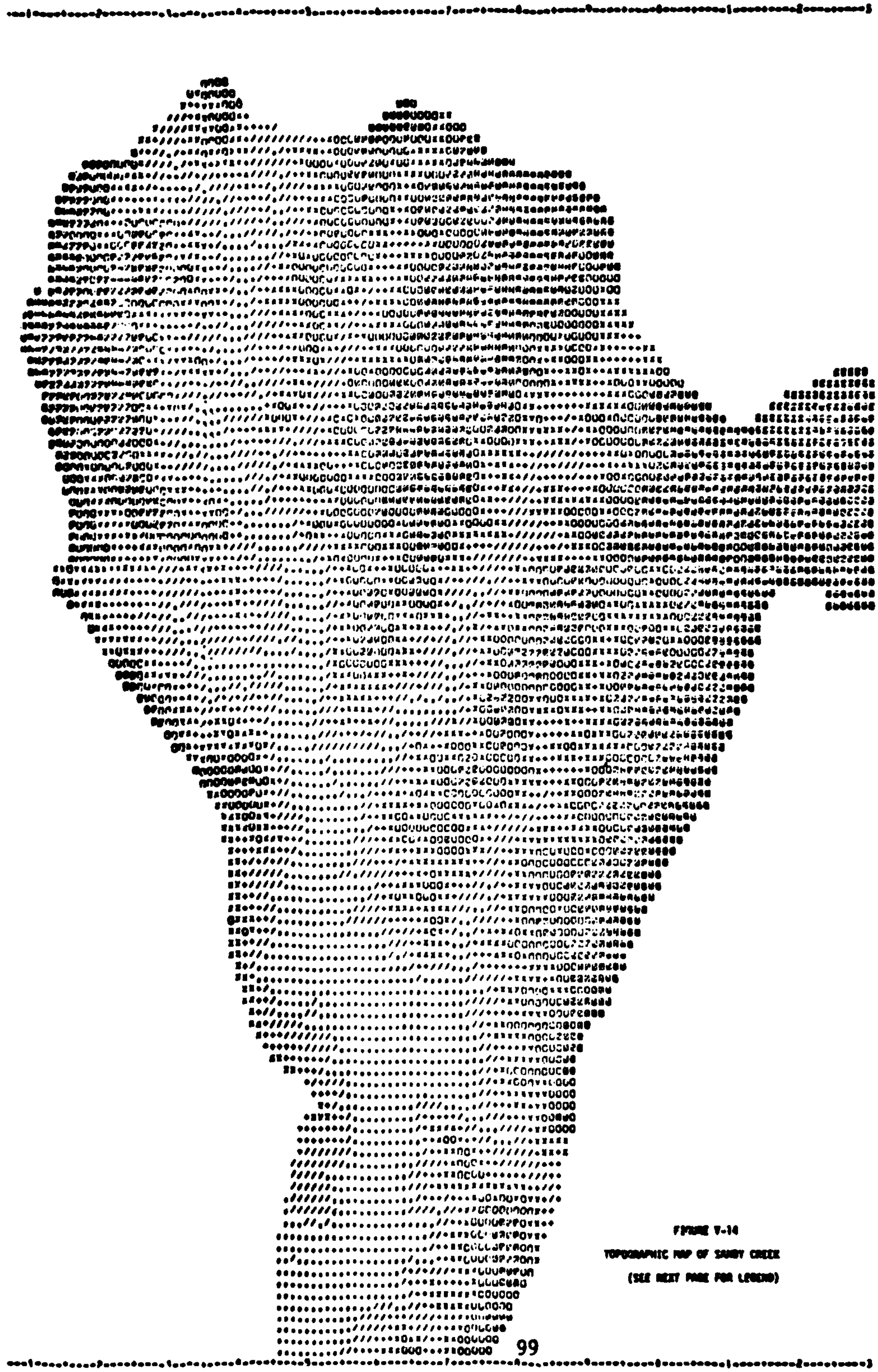

FIGURE V-14

TOPOGRAPHIC MAP OF SANDY CREEK

(SEE NEXT PAGE FOR LEGEND)

TOPO MAP

DATA VALUE EXTREMES ARE 603.000 870.000

LEVEL NUMBER	SYMBOL	VALUE RANGE	PERCENT VALUE RANGE	FREQUENCY	PERCENTILE RANGE	PERCENT OF AREAS
1	....	603.000 – 629.700	10.00	518	0.00 – 5.71	5.71
2	••••••••	629.700 – 656.400	10.00	727	5.71 – 13.73	8.02
3	////////	656.400 – 683.100	10.00	961	13.73 – 24.55	10.82
4	++++++++	683.100 – 709.800	10.00	1061	24.55 – 36.24	11.70
5	XXXXXXXX	709.800 – 736.500	10.00	1451	36.24 – 52.24	16.00
6	OOOOOOOO	736.500 – 763.200	10.00	1665	52.24 – 70.60	18.36
7	ØØØØØØØØ	763.200 – 789.900	10.00	1159	70.60 – 83.38	12.76
8	[illegible]	789.900 – 816.600	10.00	858	83.38 – 92.84	9.46
9	[illegible]	816.600 – 843.300	10.00	577	92.84 – 99.21	6.36
10	[illegible]	843.300 – 870.000	10.00	72	99.21 – 100.00	.79

LEGEND FOR FIGURE V-14

Several "smoothing" algorithms were tried to insure that all cells had outflow paths. Of these, the best appeared to be the following: set the no outflow cell's elevation equal to the average elevation of the lowest and second lowest neighboring cells. This guarantees that the cell in question has an outflow path, but may eliminate the only outflow path a neighboring cell has. The algorithm worked fairly well; after several passes the number of no outflow cells was reduced from 334 to about 18, which could not be further reduced by successive application of the algorithm. Unfortunately, this was still too high to yield acceptable results, as shown on Figure V-15. Mapped on that Figure are cell-by-cell discharges generated by 1-inch of rain in one hour. The tendency for the runoff to accumulate in stream channels can readily be seen. Note also, however, the effect of cells with no outflow path (indicated by large dots). The effect is to disconnect the basin, so that runoff from upper portions of the basin does not pass through. Sediment transport calculations based on this runoff pattern are, of course, meaningless.

If a workable algorithm cannot be developed for editing the topographic data, the procedure for initially determining cells' elevations must be modified. Automatic interpolation is one possibility. This process would rarely produce neighboring cells of exactly the same elevation. Another procedure being investigated describes topography as an array of triangular elements. Elevations are prescribed at the vertices and vary linearly within each element.

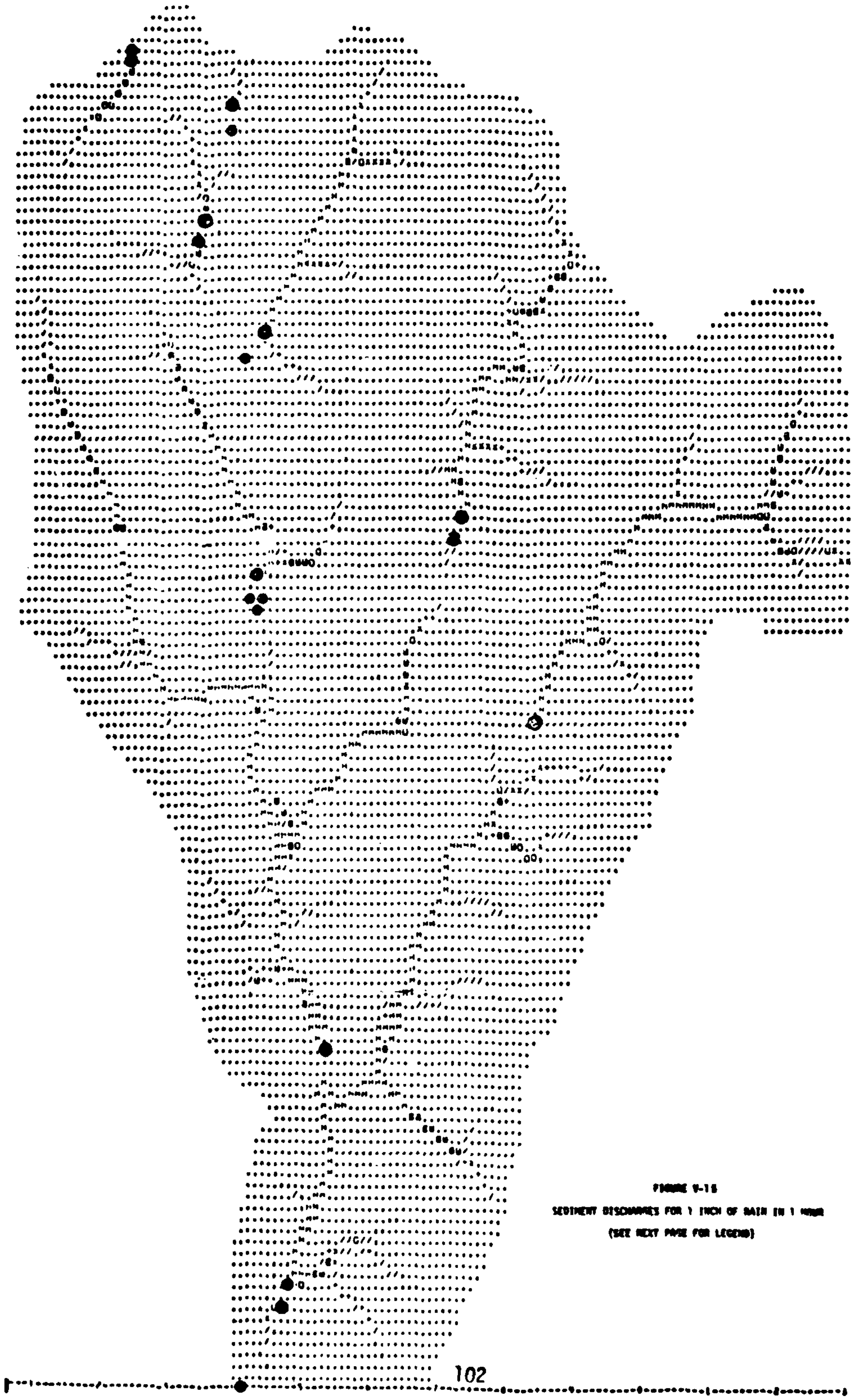

FIGURE V-16

SEDIMENT DISCHARGES FOR 1 INCH OF RAIN IN 1 HOUR

(SEE NEXT PAGE FOR LEGEND)

DISCHARGES, 1 INCH OF RAIN IN 1 HOUR.

DATA VALUE EXTREMES ARE 0.000 5.000

LEVEL NUMBER	SYMBOL	VALUE RANGE	PERCENT VALUE RANGE	FREQUENCY	PERCENTILE RANGE	PERCENT OF AREAS
LOW	LLLLLLLL LLLLLLLL LLLLLLLL	0.000 0.000		0	- 0.00 0.00	0.00
1	....	0.000 .500	10.00	8165	0.00 89.25	89.25
2	•••••••• •••••••• ••••••••	.500 1.000	10.00	299	89.25 92.51	3.26
3	//////// //////// ////////	1.000 1.500	10.00	165	92.51 94.31	1.80
4	++++++++ ++++++++ ++++++++	1.500 2.000	10.00	61	94.31 95.19	.88
5	XXXXXXXX XXXXXXXX XXXXXXXX	2.000 2.500	10.00	56	95.19 95.80	.61
6	OOOOOOOO OOOOOOOO OOOOOOOO	2.500 3.000	10.00	29	95.80 96.12	.32
7	ØØØØØØØØ ØØØØØØØØ ØØØØØØØØ	3.000 3.500	10.00	31	96.12 96.46	.34
8	88888888 88888888 88888888	3.500 4.000	10.00	22	96.46 96.70	.24
9	@@@@@@@@ @@@@@@@@ @@@@@@@@	4.000 4.500	10.00	16	96.70 96.87	.17
10	ZZZZZZZZ ZZZZZZZZ ZZZZZZZZ	4.500 5.000	10.00	13	96.87 97.01	.14
HIGH	HHHHHHHH HHHHHHHH HHHHHHHH	5.000 5.000		274	97.01 100.00	2.99

LEGEND FOR FIGURE V-15

VI REFERENCES

(1) Storage, Treatment, Overflow, Runoff Model (STORM) Users Manual, The Hydrologic Engineering Center, July 1976.

(2) Water Quality for River-Reservoir Systems, WQRRS, Generalized Computer Program, The Hydrologic Engineering Center, 1977.

(3) Water Surface Profiles, HEC-2, Generalized Computer Program Users Manual, The Hydrologic Engineering Center, October 1973.

(4) Geometric Elements from Cross Section Coordinates, GEDA, Generalized Computer Program, The Hydrologic Engineering Center, June 1976.

(5) "Adaption of Water Quality-Ecological Model to the Oconee River System", Letter Report to The Hydrologic Engineering Center, Donald J. Smith, September 28, 1976.

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(7) Kramer, Chin and Mayo; Water Resources Engineers, Yoder, Trotter, Orlob and Associates, for the Seattle District U.S. Army Corps of Engineers, "Environmental Planning for the Metropolitan Area, Cedar Green River Basin, Washington, Urban Drainage Study", Appendix C Storm Water Monitoring Program, December 1974.

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(11) Personal Communications, U.S. Soil Conservation Service, Athens, Georgia.

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(13) "Chattahoochee River Water Quality Analysis", R. G. Willey and Dennis Huff, Hydrologic Engineering Center, December 1975.

(14) Foster, G. R. and Meyer, L. P., "Mathematical Simulation of Upland Erosion by Fundamental Erosion Mechanics," in Present and Prospective Technology for Predicting Sediment Yields and Sources, Agricultural Research Service, June 1975.

(15) Kilinc, M., and Richardson, E. V., "Mechanics of Soil Erosion from Overland Flow Generated by Simulated Rainfall," Colorado State University Hydrology Papers, No. 63, September 1973.

(16) Vanoni, Vito A., ed., "Sedimentation Engineering," ASCE Manual 54, 1975.

APPENDIX A

SMITH REPORT

ADAPTION OF WATER QUALITY - ECOLOGICAL MODEL TO THE OCONEE RIVER SYSTEM

By

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BACKGROUND AND PURPOSE

The U.S. Army Corps of Engineers Hydrologic Engineering Center (HEC) is adapting a dynamic water quality-ecological model to a portion of the Oconee River in Georgia. While the model is designed to calculate the population dynamics of algae, zooplankton, benthic animals and fish, detailed calibration of that portion of the model is beyond the limited scope of this project. Since the primary purpose of the model will be to evaluate the transient water quality impact of storm runoff and waste discharges, the organic sediment and the biological section of the model will remain constant during the simulation.

In lieu of modeling those parameters which were held constant, pertinent reports of water quality and biological surveys were reviewed to estimate their values.

This brief report documents the findings of this review.

RIVER SYSTEM

The study is limited to the upper reaches of the Oconee River system near Athens. Included is the Oconee River between the Barnett Shoals Dam and the confluence of the Middle Oconee and North Oconee Rivers and approximately twenty-five (25) miles of the Middle Oconee River and twenty (20) miles of the North Oconee River.

The Middle and North Oconee Rivers are typically 1/2 to 5 feet deep and from 50 to 100 feet wide. The Oconee is also typically 50 to 100 feet wide with depths up to 8 feet. The average gradient is approximately 4 feet per mile and velocities are characterized as slow to moderate.

Urban development is limited to the Athens area. The remaining watershed is rural with many wooded areas. A total of approximately seven (7) million gallons a day of municipal and industrial waste water is discharged to the Middle Oconee and North Oconee after secondary treatment. During periods of high runoff, significant amounts of organic detritus and sediment are washed into these rivers from the watershed.

WATER QUALITY

For purposes of characterizing the water quality, the river system can be divided into two sections. Section One includes the Oconee River and those portions of the Middle Oconee and North Oconee below the two Athens sewage treatment plant outfalls. Water quality in this section is influenced by the Athens sewage treatment plant effluent. Dissolved oxygen is lower and plant nutrients, BOD, and total organic carbon are higher than in Section Two. Water quality in Section Two, the remaining portion of the study area, is reasonably good. The water of both sections is quite turbid during periods of high flow. Levels of selected water quality parameters reported by state and federal agencies are summarized in Table 1.

ALGAE AND ZOOPLANKTON

No chlorophyll _a_ data or other direct measurement of suspended algae are available. Some attached algae (periphyton) and the macrophyte

Table 1

WATER QUALITY OF UPPER OCONEE RIVER SYSTEM

	Temperature		Dissolved Oxygen (% Saturation)			5 day BOD	Nitrogen		Phosphorus	Total Organic Carbon
							NO_2+NO_3	NH_3		
	Min	Max	Avg	Min	Max	mg/l	mg/l	mg/l	mg/l	mg/l
Section 1	5	26	79	66	91	2.2	.60	.18	.18	3.6
Section 2	5	28	87	74	94	.5	.38	.02	.05	3.3

Podostemum have been observed where suitable rock substrate is available. Nelson (1962) reports _Podostemum_ levels of 10 to 15 g/m^2 (dry weight) on the Middle Oconee where ideal substrate conditions exist and none on sand or mud substrates. Suitable substrate (bedrock and cobbles) should exist where velocities are sufficiently high to prevent deposition of sand and silt. If we assume velocities are sufficiently high with bottom slopes of 1 foot in 200 feet and average bottom slope of 4 feet in one mile, approximately 15% of the substrate is suitable. Fifteen percent of the densities reported by Nelson yield average macrophyte and periphyton densities from 1.5 to 2.25 g/m^2.

An examination of dissolved oxygen data indicates that algal photosynthetic oxygen production is not significant. Dissolved oxygen never exceeded saturation and no diurnal variation was evident. No depletion of plant nutrients was observed in the data. Nelson also reported that no detectable differences in dissolved oxygen was observed between upstream and below his study area.

For modeling purposes, both algae and zooplankton concentrations can be presumed low, near zero.

BENTHIC ANIMALS

The make up of the benthic animal (microinvertebrates) population has been studied by submerging limestone substrate (LSS) in the water for two months. The results of these studies indicate that benthic animals can survive throughout the study area if suitable substrates exist. Unfortunately the test results do not include total biomass or LSS surface areas, therefore, population densities cannot be determined.

Nelson (1962) observed benthic animal population densities of 2 to 10 g/m^2 (dry weight) with ideal substrate conditions. If we also assume fifteen percent (15%) of the natural substrate is suitable for benthic animals, average densities of .3 to 1.5 g/m^2 can be expected.

FISH

Fish population data within the study area are limited to one sampling event in June 1959. Total fish mass was reported. However, the length of stream sampled was omitted making it impossible to calculate fish biomass per mile. All fish collected were warm water species. Approximately fifty percent (50%) were bottom feeding fish.

Streams of this type typically have a fish population of 100 to 300 lb/acre (wet weight). Assuming an average channel width of 75 feet, approximately 600 feet of channel has a surface area of one acre. Converting to dry weight per mile, a total biomass of 90 to 260 lbs/mile or 40 to 120 kg/mile is obtained.

DETRITUS AND ORGANIC SEDIMENT

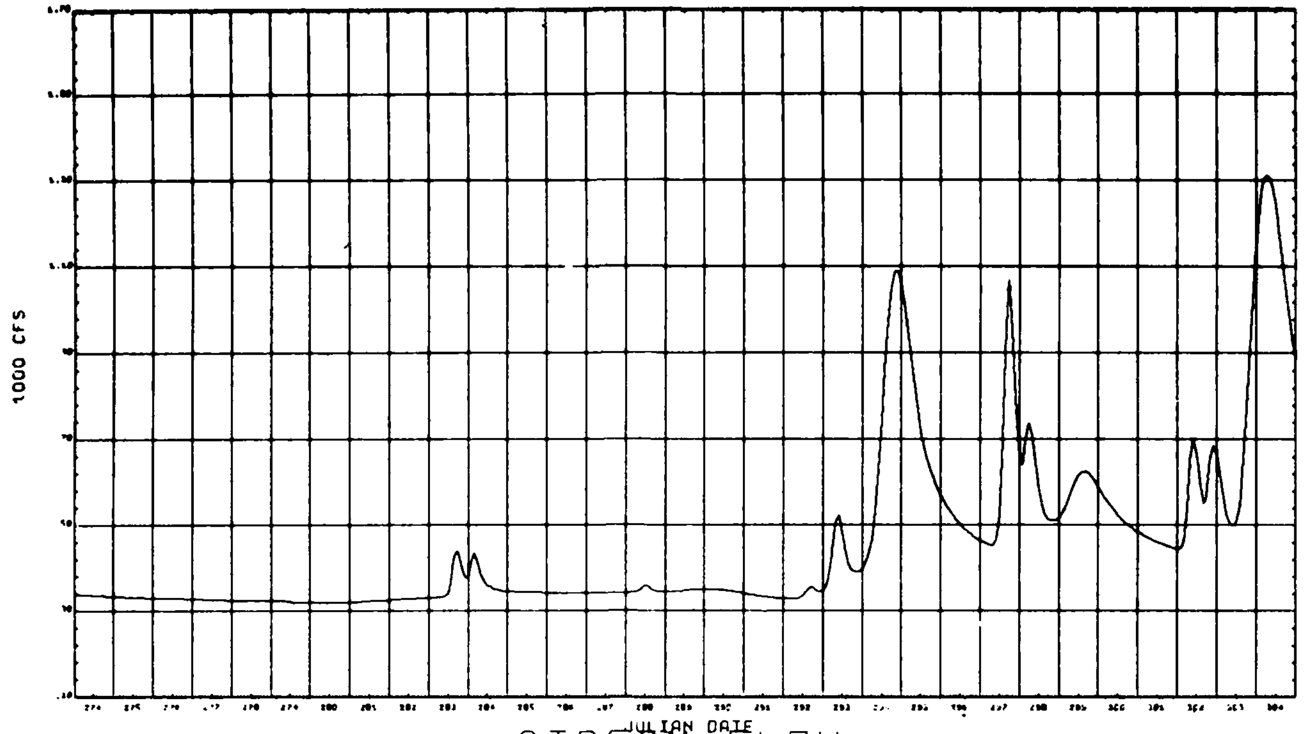
Total organic carbon in the water ranged from 2 to 7 mg/l C. The detritus concentration in the water is generally twice the organic carbon level or 4 to 14 mg/l. The detritus level is generally a function of flow rate, increased detritus occuring with increased flow. Nelson (1962) attempted to correlate river discharge with detritus volatile solids) with some success. He typically measured volatile solids of 1 to 10 mg/l at moderate flows and up to 50 mg/l during high flow periods.

Nelson also measured settleable plant and animal detritus and reported typical values of 12 to 20 g/m^2. Below the Athens STP outfalls, suspended detritus and organic sediment can be expected to increase. A 10 to 20 percent increase in the above values seems appropriate.

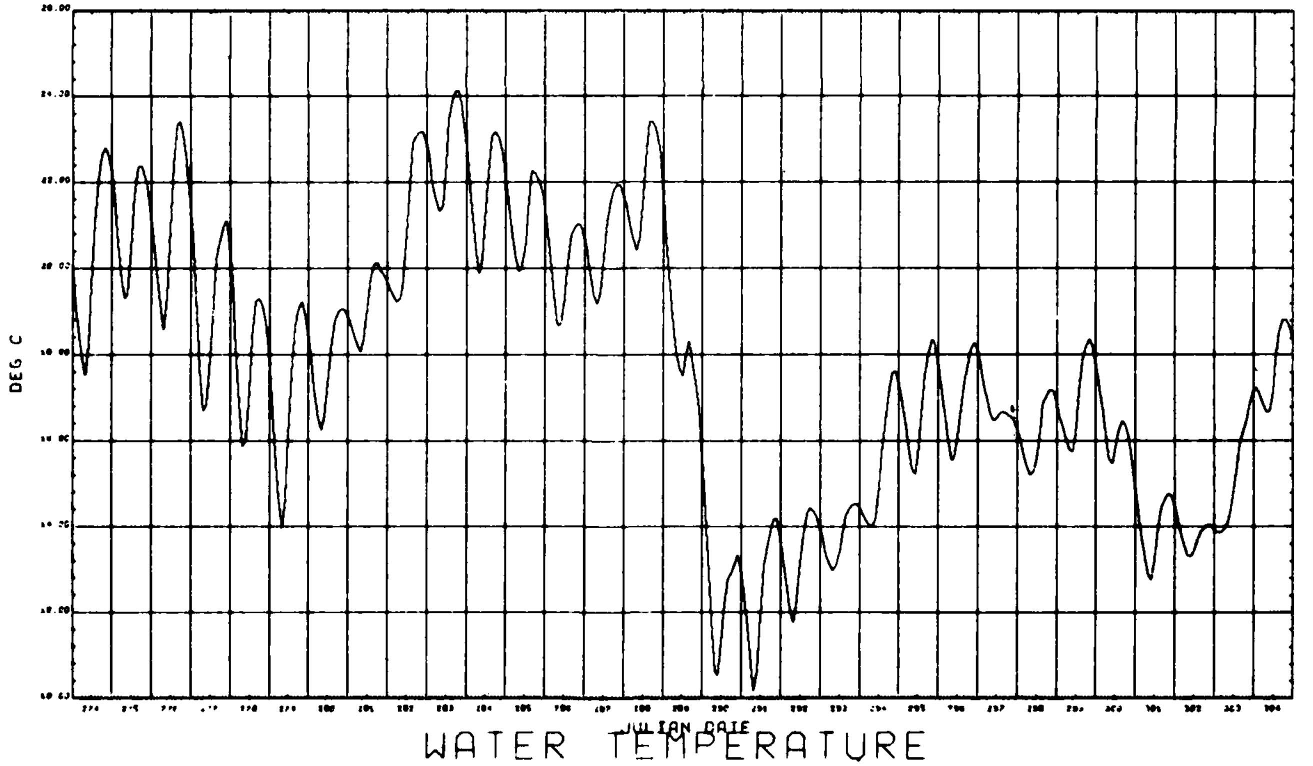
Nelson, Daniel J., and Scott, Donald C., 1962, Role of detritus in the productivity of a rock-outcrop community in a piedmont stream. Department of Zoology, University of Georgia.

APPENDIX B

QUALITY PROFILES



STREAM FLOW

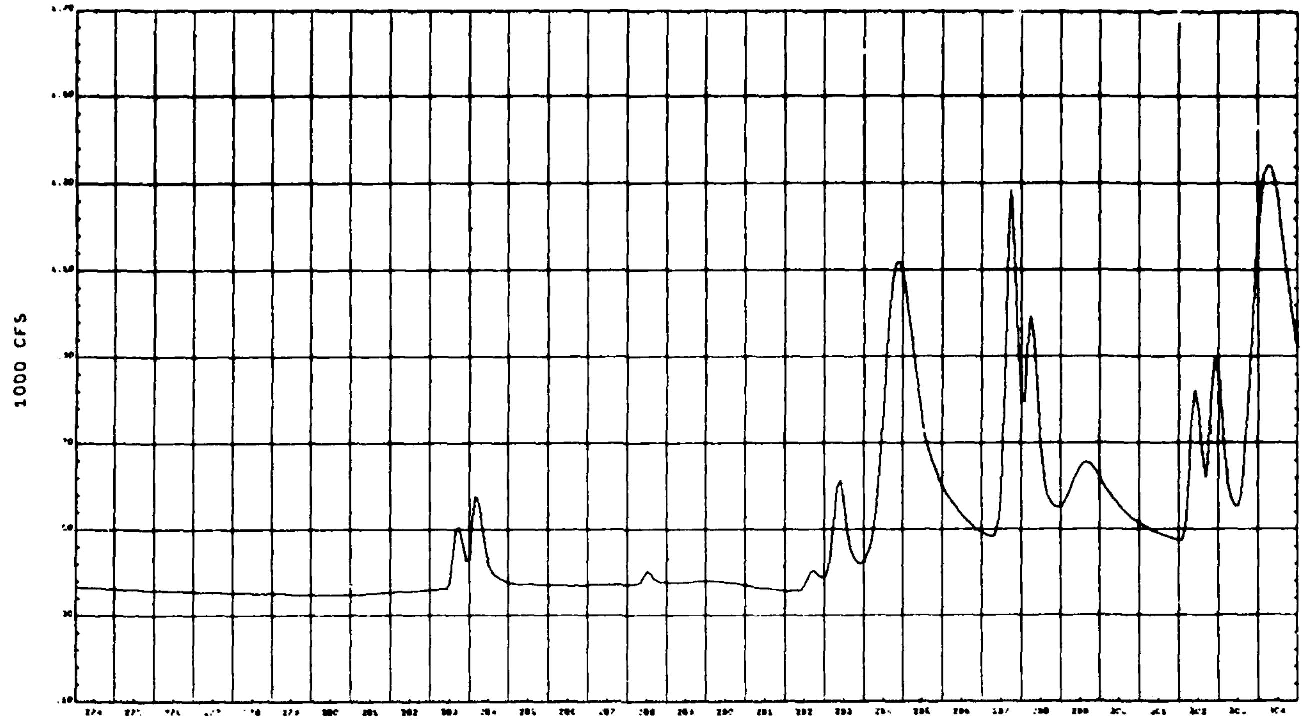


WATER TEMPERATURE

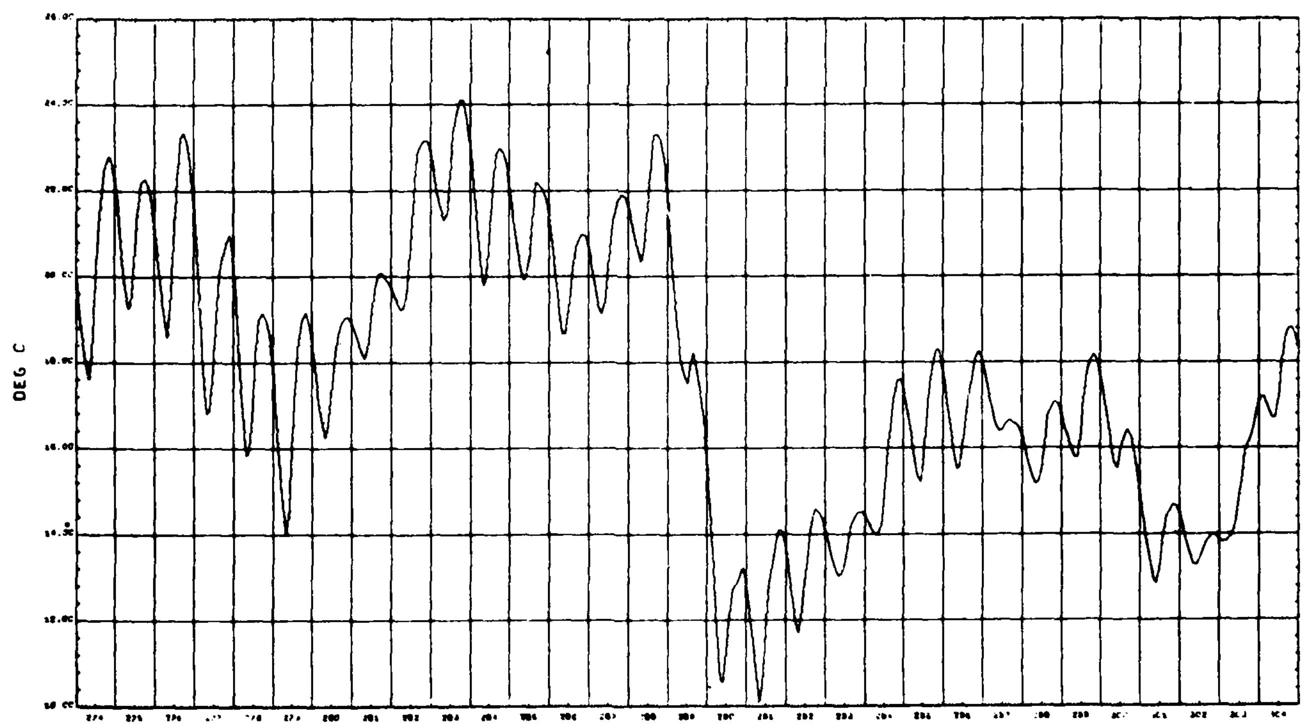
OCONEE RIVER AT BARNETT SHOALS DAM

EXISTING LAND USE

1-31 OCTOBER 1970



STREAM FLOW

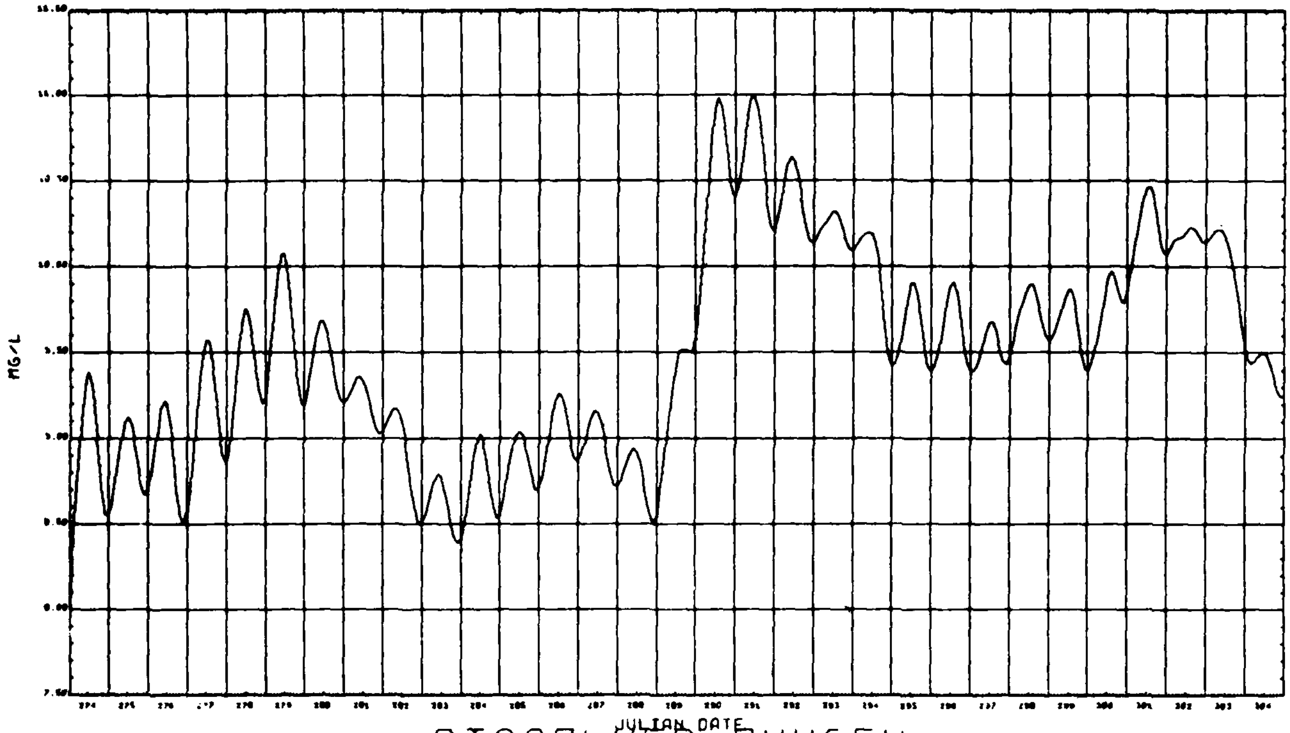


WATER TEMPERATURE

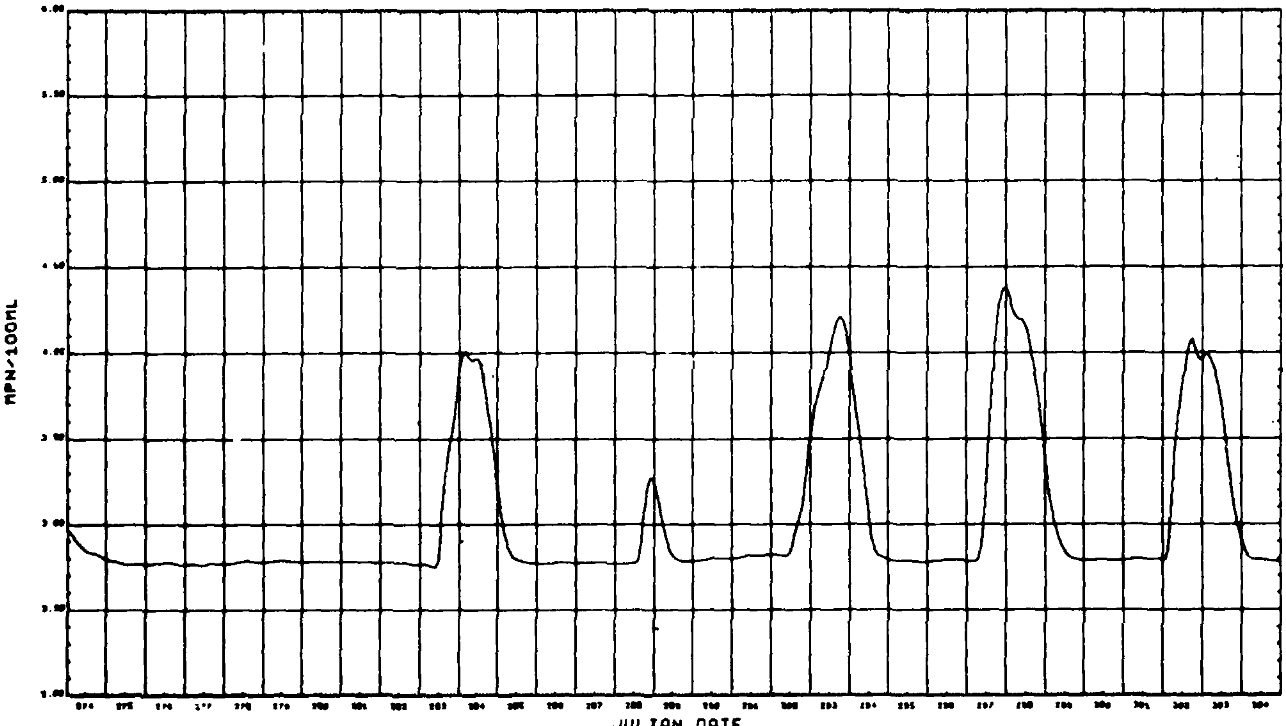
OCONEE RIVER AT BARNETT SHOALS DAM

ALT. C LAND USE

1-31 OCTOBER 1970



DISSOLVED OXYGEN

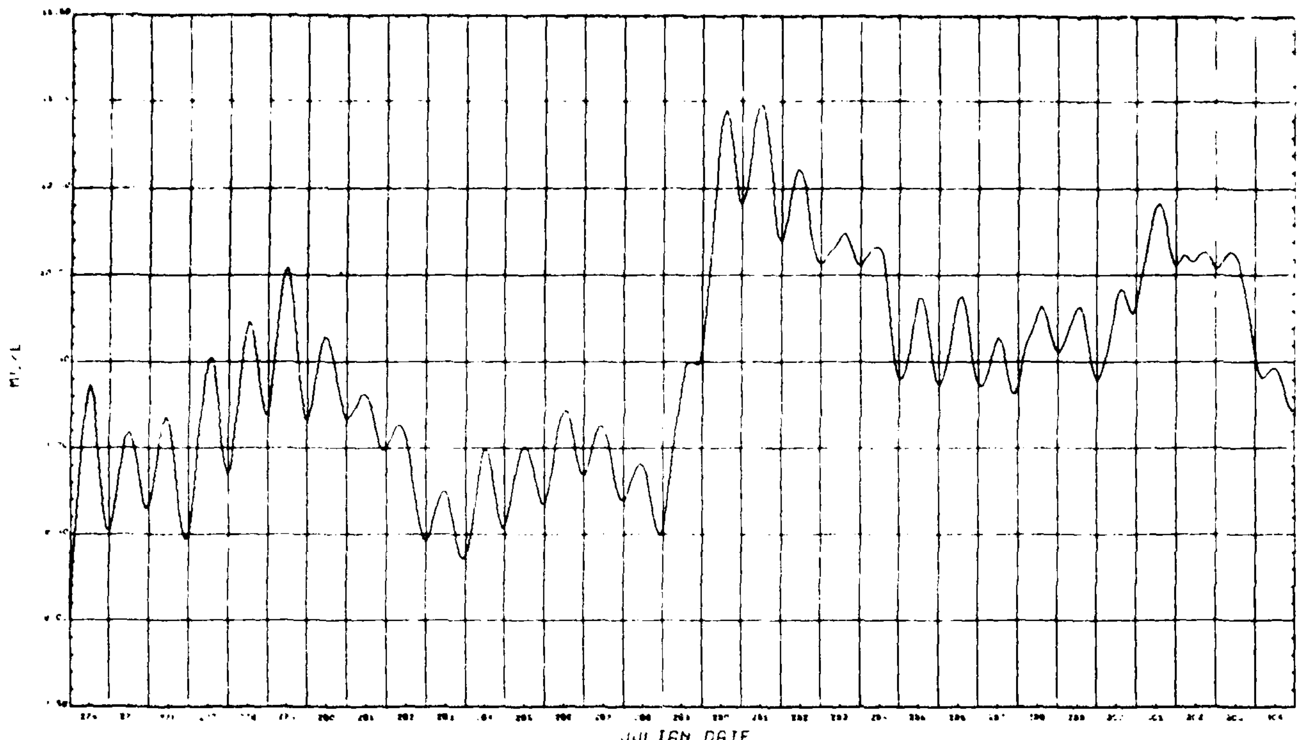


LOG COLIFORM

OCONEE RIVER AT BARNETT SHOALS DAM

EXISTING LAND USE

1-31 OCTOBER 1970



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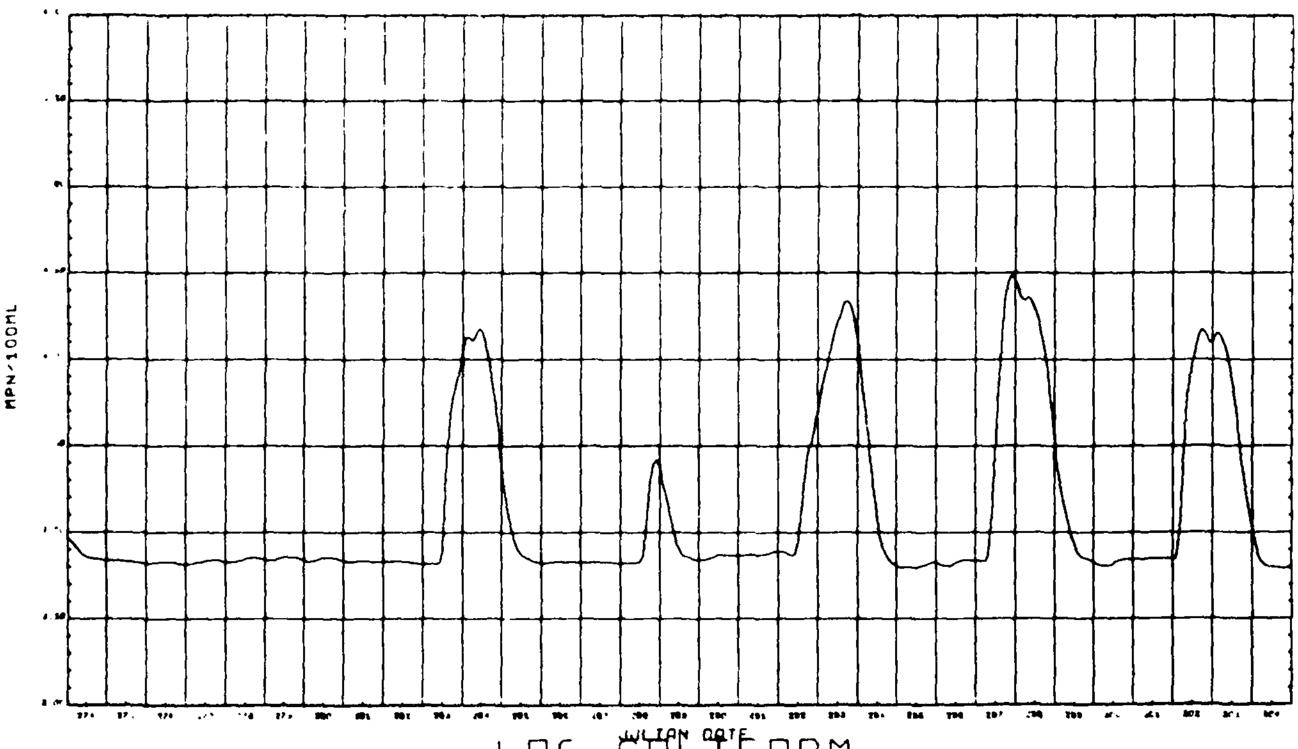
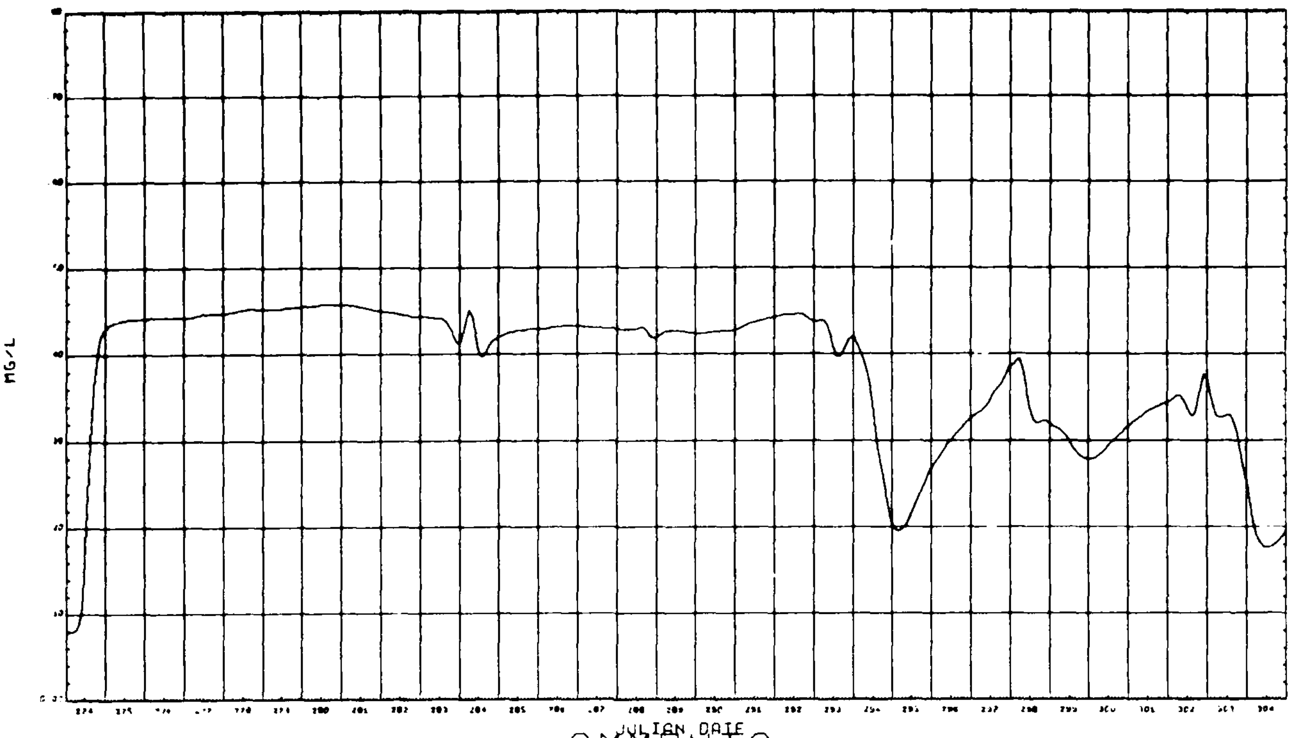


LOG COLIFORM

OCONEE RIVER AT BARNETT SHOALS DAM

ALT. C LAND USE

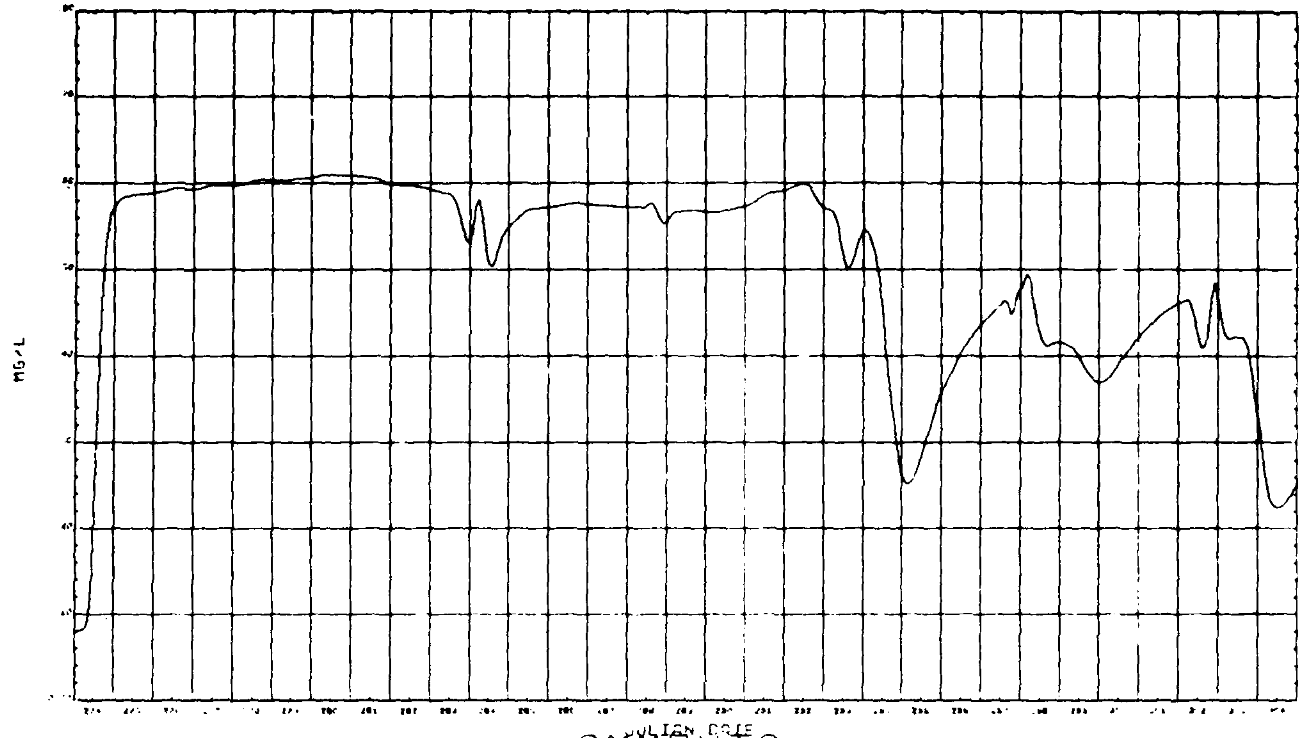
1-31 OCTOBER 1970



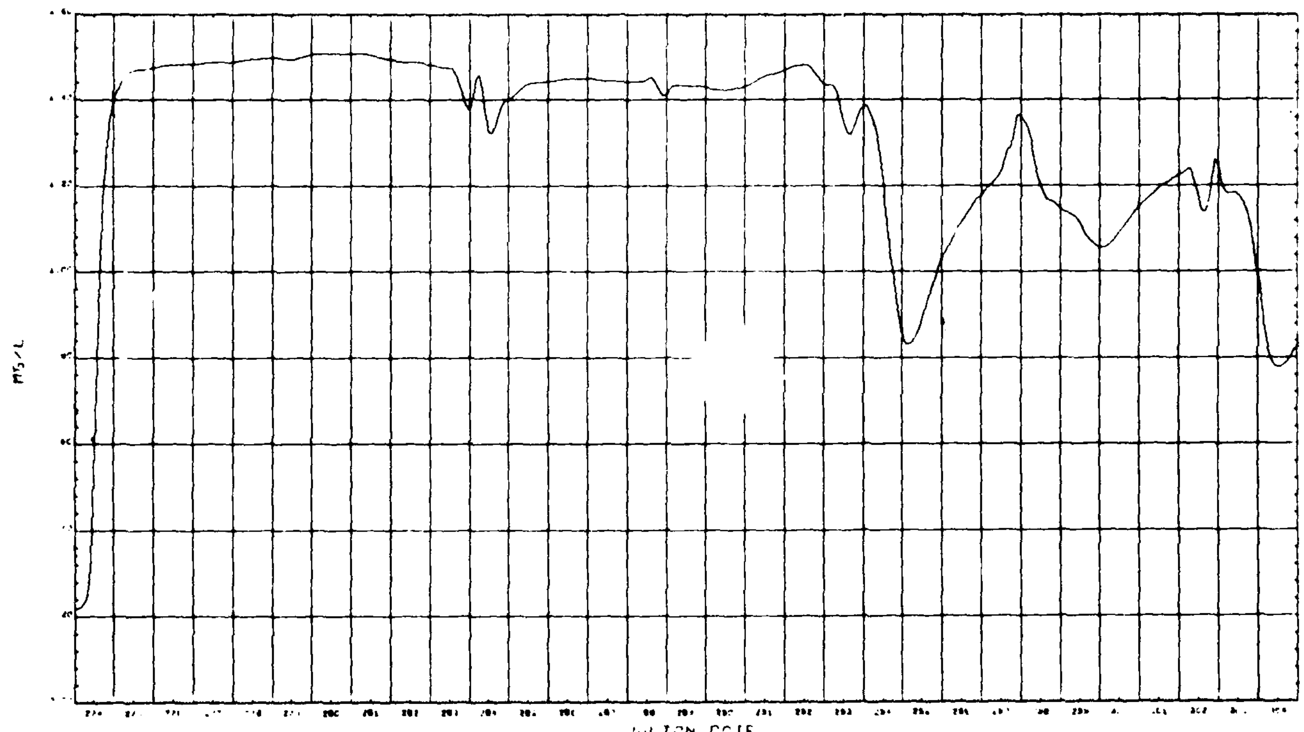
AMMONIA

NITRATE

OCONEE RIVER AT BARNETT SHOALS DAM
EXISTING LAND USE
1-31 OCTOBER 1970



AMMONIA

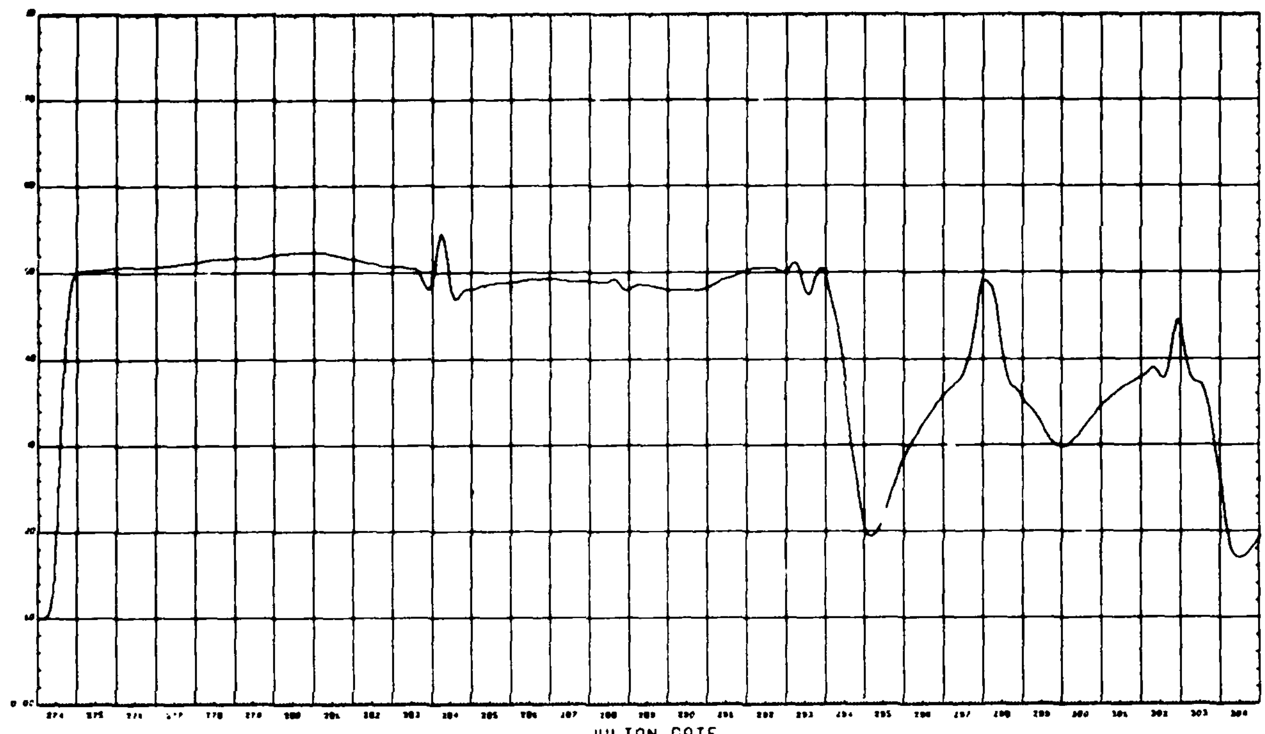


NITRATE

OCONEE RIVER AT BARNETT SHOALS DAM

ALT. C LAND USE

1-31 OCTOBER 1970

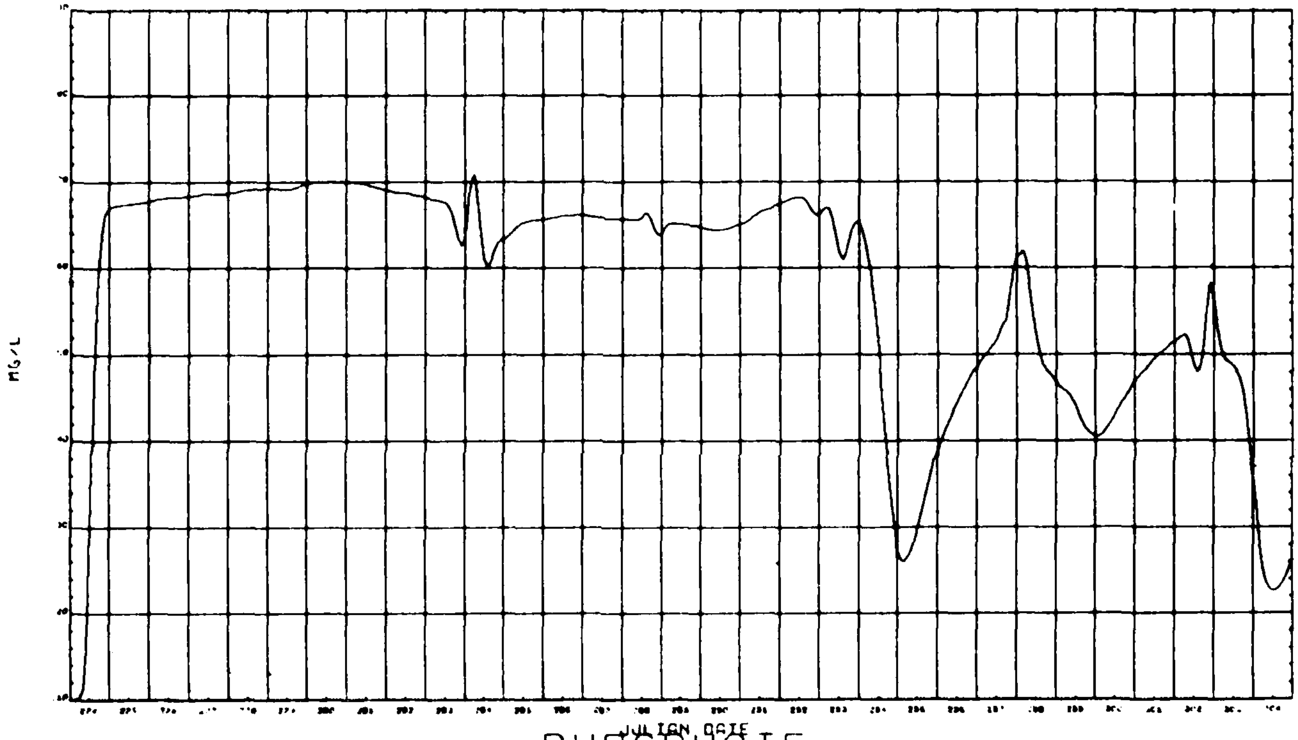


PHOSPHATE

OCONEE RIVER AT BARNETT SHOALS DAM

EXISTING LAND USE

1-31 OCTOBER 1970



PHOSPHATE

OCONEE RIVER AT BARNETT SHOALS DAM

ALT. C LAND USE

1-31 OCTOBER 1970